

The University of Chicago

ECOLOGICAL STUDIES ON THE
HIGH PLATEAUS OF UTAH

A DISSERTATION SUBMITTED TO THE FACULTY
OF THE DIVISION OF THE BIOLOGICAL SCIENCES
IN CANDIDACY FOR THE DEGREE OF DOCTOR
OF PHILOSOPHY

DEPARTMENT OF BOTANY

1933

By
HELEN DIXON

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ECOLOGICAL STUDIES ON THE HIGH PLATEAUS OF UTAH

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HELEN DIXON

(WITH THREE FIGURES)

Introduction

The region studied is located mainly in Wayne County, Utah, but it includes parts of Sevier County (in the vicinity of Fish Lake) and of Garfield County (Boulder Mt. on Aquarius Plateau). It lies within a quadrangle extending from 111° to 112° west longitude and from 38° to $38^{\circ}45'$ north latitude. The altitudinal range is from 5250 feet at Notom to 11,600 feet on the tops of the High Plateaus.

The drainage is into the Colorado River by way of the Fremont River. Physiographically the region belongs to the province designated by the Powell Survey (3) as "the High Plateaus of Utah." Because of its sparse population and its inaccessibility to the ordinary traveler, it is comparatively unknown and is still unspoiled by tourists.

Geology and topography

The geology was first worked out in 1879 by Capt. C. E. DUTTON of the Powell Survey (3). Little scientific work has been done in this territory since then. The Plateau Province of Powell has been above the sea since the close of the Cretaceous. Tertiary lacustrine deposits and lava flows have covered the earlier marine deposits. The present altitude of over 11,000 feet is due mainly to subsequent faulting and uplift.

The highlands considered in this report comprise the southern half of the easternmost of the three belts of Powell's High Plateaus. They include the Fish Lake Plateau with Mts. Marvine, Terrill, and Hilgard, its outliers northeast of it, the Awapa Plateau, Thousand Lake Mt., and the Aquarius Plateau.

Fish Lake Plateau is a small tableland 10-15 miles long by 2-5 miles wide. It reaches a maximum altitude of 11,600 feet. Except

along its southwest margin where it merges with the Awapa Plateau, it is bounded by precipitous lava walls such as the Grass Valley fault-scarp, a 4300 foot cliff on the northwest, and the 2700 foot cliff above the lake on the southeast side.

There is evidence of glaciation during the Pleistocene. The location of the terminal moraines at 9000 feet in Fish Lake Basin and in Summit and Moraine valleys, however, disproves any glacial origin for the lake basin itself, the lake level being 8750 feet. DUTTON (3) found evidence of a former outlet into the Great Basin at the south end of the lake. In the process of uplifting, the basin was so tilted that the drainage was reversed. The water of Fish Lake now joins that of Seven Mile Creek at the north end, and together they flow through the Fremont Reservoir into the headwaters of the Fremont River and thence into the Colorado River.

Fish Lake is a deep body of water 6 miles long and nearly 2 miles wide. Its west wall rises steeply 2600 to 2700 feet to the top of the plateau. The east wall is even more abrupt but not so high, only 1700 feet. Just over its crest are the two Crater Lakes.

The Awapa Plateau adjoining Fish Lake Plateau on the southeast was uplifted with the latter along the Grass Valley fault. Its western front stands 2000 feet above Grass Valley. Awapa Plateau has an area of about 700 square miles. Its surface is a rocky lava slope descending from 9000 feet at the northwest, west, and southwest rims to Rabbit Valley, a crescent shaped depression lying at 7000 feet above the sea. The Fremont River flows through this valley after its descent from the Fish Lake Highlands and deposits here much of its load, forming a rich alluvial plain.

Rising above Rabbit Valley along the concave side of the crescent is Thousand Lake Mt. It too is a remnant of erosion, having been separated from the Aquarius Plateau by the work of the Fremont River and its tributaries. Thousand Lake Mt. is an even smaller table than Fish Lake Plateau, its nearly level lava-capped summit being about 5 miles long and not quite 2 miles wide. To the east and southeast is the great rock desert of the Water Pocket Flexure, while to the south across the Fremont Valley is the Aquarius Plateau.

At the lower end of Rabbit Valley, the Fremont River passes through the Red Gate into a series of canyons and gorges cut

through 2500 feet of brilliantly colored sediments on its 100 mile course to the Colorado River.

High above all of this is the Aquarius Plateau, which lies within the Powell National Forest, the largest forest in Utah. This plateau is roughly L-shaped, 35 miles long by 10-18 miles wide. Its altitude ranges from 10,500 feet on the south and west to 11,600 feet on the east, where it stands 5500 to 6000 feet above the rock desert at its base. The lava cap varies from 1000 to 2000 feet in thickness. Over three-fourths of its margin is bounded by massive cliffs at the bases of which are steep talus slopes. Numerous glacial lakes, cirques, and moraines furnish evidence that the summit and upper slopes have been glaciated.

Both the Water Pocket Flexure and Miner's Mt. are subsidiary domes extending southeast from below the Red Gate and rising to 8250 feet. They have been deeply and intricately dissected by narrow gorges and canyons antecedent to their uplift. Most of the gorges are dry except during a rain; but cloudbursts occasionally bring a head of water 15 to 20 feet high rushing through the washes, destroying all in its path.

The Water Pocket Flexure has been of interest to the mineralogist because of its deposits of copper and uranium; to the paleontologist because of the abundant Triassic material, and to the anthropologist because of the interesting remains of the Fremont culture of the cliff-dwellers found in its canyon walls. Botanically it is of interest as a northern outpost of the Lower Sonoran desert vegetation.

Climate

The latitudinal extent of this area is only three-fourths of a degree, but its altitudinal range is 6000 feet. Figures from the records of the United States Weather Bureau (1) corroborate SAMPSON'S (5) statement that climatic differences due to altitude are intensified by the type of relief features peculiar to Utah. The length of the growing season, the temperature, precipitation, rate of evaporation, wind, all of these vary greatly even in as small an area as that under consideration. In the lowlands the growing season is two or three times as long (180 to 200 days) as on the tops of the plateaus (60 to 90 days). This factor alone would show its effects on the plant cover.

PRECIPITATION.—Although dependent somewhat upon altitude, precipitation is more affected by topography. Loa, at 7000 feet, has less precipitation than St. George at 2880 feet. BOWMAN (2) remarks that most of the High Plateaus are as dry as southwestern Arizona at one-half the altitude. DUTTON (3) and SAMPSON (5) point out that all lands below 7000 feet in the plateau country are deserts, receiving less than 8 inches of precipitation per year.

The zones lying above 7000 feet receive more moisture than the lowland stations. BOWMAN (2) estimates that the Aquarius Plateau receives 24–30 inches. Fish Lake Plateau and Thousand Lake Mt. probably get as much, for their vegetation is similar. SAMPSON gives figures for three of the forest zones. The aspen-Douglas fir zone is the wettest, receiving 25–29 inches per year. The Engelmann spruce zone comes next with 25.9 inches. The western yellow pine zone has an average of only 19 inches. No figures are given for the piñon-cedar zone, but it probably gets about 15 inches per year. SAMPSON found the average monthly precipitation during the summer to be as follows:

Engelmann spruce zone	2.16 inches
Douglas fir-aspen zone	2.44 inches
Western yellow pine zone	1.52 inches

EVAPORATION.—Owing to their higher temperature and lower humidity, as well as to their scantier precipitation, the lowest altitudes have the highest rates of evaporation. There is a gradual decrease up to the aspen zone, where it reaches a minimum. In spite of its lower temperature, there is an increase in the spruce zone over that of the zone below. This is due not only to lower precipitation, but also to higher winds. During the growing season, the aspen-Douglas fir zone has a total wind of 12,500 miles, compared with that of 27,500 miles in the Engelmann spruce zone (9).

Soils

The soils of the region vary widely in their physical and chemical composition. Residual lava soils occur chiefly on the tops of the High Plateaus, and also on the entire surface of the Awapa Plateau. They are usually thin and stony, owing to the resistant character of

the parent rock. Their moisture content therefore is low and their air content high.

Residual sands, gravels, and clays are found below the lavas on all of the plateaus. Sands and clays are most abundant and show contrasting vegetation in the same climatic zone.

Residual limy soils are less common. On the northeast face of Aquarius Plateau at about 7500 feet altitude is a spur of richly calcareous soil derived from gypsum. Growing here, as at Bryce Canyon where the soil is from a very calcareous sandstone, is *Pinus aristata*.

Residual organic soils accumulate best in poorly drained depressions and usually support a meadow vegetation. A vein of peat 2-3 feet below the surface of glacial till in the *Pinus ponderosa* forest indicates a former climate somewhat different from that of the present. Humus layers cover other soils on all vegetated surfaces.

Aeolian soils in the form of dunes are piled against the White Cliff domes on the sandstone ledges and on a miniature scale on the floodplain of the Fremont River. These soils are like the residual sands except that they are less stable.

Alluvial soils are largely under cultivation. They occur most plentifully in Rabbit Valley and in the Fremont Valley at Fruita. Slope wash has helped to fill Summit Valley and the Fish Lake basin. Alluvium is usually deep and level and better watered than surrounding areas. Its vegetation is therefore distinct.

Lacustrine soils are found along the shores of shallow lakes. Like stream-borne soils, they are level, deep, and well watered. In addition they are usually fine and richer in humus although their drainage is poorer.

Glacial drift is restricted to levels above 9000 feet at Fish Lake and perhaps on the other plateaus. Terminal moraines exist at this level.

Talus, because of its coarseness, usually supports only pioneer stages of vegetation. In the montane zone such soil more frequently develops a conifer rather than an aspen forest. Perhaps the crevices where seeds may start are too dark for aspens.

Most of the soils were circum-neutral (pH 6.8-7.2). The meadow soils showed pH 6.8 or above; soil from the Atriplex desert at Notom

tested pH 7.8-8.0; while the mud flats on the shores of the Crater Lakes at 9750 feet had a pH of 7.3.

Vegetation

The various plant zones, like the belts of climate, are more or less dovetailed together. The southern limit of this area seems to be drawn on the tension line between the upper and lower Sonoran zones, for in the arid regions beyond the Red Gate such conditions exist as permit the advance of the vanguard of the lower Sonoran flora into territory which theoretically should be northern desert.



FIG. 1.—Alkali desert below Notom showing greasewood-shadscale association; *Populus fremontii* along the wash. Photograph by S. B. Spira.

Only a few of the southern desert forms have succeeded in climbing over the rim into the Great Basin. The desert areas on the basin side of the divide are occupied by the northern desert formation dominated by *Artemisia tridentata*. Both of these formations are replaced, at least temporarily, on alkali soils by *Sarcobatus vermiculatus* and its associates (fig. 1). Above the desert, in the cooler, less arid zone extending from 6000 to 7500 feet, are extremely open stands of scrub timber. Near Fruita this zone is occupied by the southern semidesert formation consisting chiefly of *Pinus edulis* and *Juniperus utahensis*, with some northern desert species. The cedar-piñon association forms a belt also above the *Artemisia tridentata* zone on

Thousand Lake Mt., Aquarius Plateau, and the extreme rim of the Awapa Plateau above 8000 feet.

The northern semidesert is likewise characterized by the cedar; but instead of by piñon, it is accompanied by *Cercocarpus*. It separates the sagebrush desert from the montane forest on the west face of Fish Lake Plateau.

There are two other associations between the desert and the forest which are probably only subclimaxes here. In some places are nearly pure stands of *Quercus utahensis*. In others a chaparral consisting of *Arctostaphylos platyphylla* is conspicuous. The composition of the scrub forest zone seems to vary somewhat with edaphic conditions.

Where the rainfall is 15 to 20 inches, the slopes not too steep, and the soil well drained, open but practically pure stands of *Pinus ponderosa* occur. These are the first true forests. The trees are tall and straight and not so scattered as in the semidesert. They form the climax association on the northern and eastern slopes of the Aquarius Plateau from 7500 to 9000 feet, and at about 8000 feet on some of the sandy spurs on the east face of Thousand Lake Mt. Isolated groups occur as low as 5000 feet in favorable situations on Miner's Mt. and the Water Pocket Flexure. There are no western yellow pines on either Fish Lake or the Awapa Plateaus.

Above the western yellow pine forest occurs the most mesophytic plant association in all Utah, the montane forest. In this region it is best developed from about 8700 to 9500 feet, but may extend far down along mountain streams, even into the piñon zone. The dominant trees are *Pseudotsuga mucronata* and *Populus aurea*. Mixed with them are *Abies concolor* and *Picea pungens*. This formation is well represented on all three of the High Plateaus.

The subalpine forest consists mainly of Engelmann spruce; but in places *Abies lasiocarpa* is abundant. Both aspens and Douglas firs extend well up into this zone. The main stand of the subalpine forest lies between 9500 feet and 11,000 feet on these plateaus. It extends down to 9000 feet in canyons and exists only as scattered bunch forests beyond 11,000 feet.

The alpine meadow formation occupies valleys and depressions at the subalpine level. *Caltha rotundifolia*, *Polygonum bistortoides*,

Phleum alpinum, and *Pedicularis groenlandica* seem to be constant members of this association. The alpine meadow may represent a permanent climax or a long-time temporary climax. Whichever may be the case, it is a characteristic feature of the landscape in the sub-alpine zone.

In the open spaces on the summits and high ridges the soil is thin and stony, and because of its good drainage and exposure to high winds, it is dry. Here an alpine scrub made up of prostrate shrubs and minute mat-forming herbs develops. This alpine-desert climax is found on the tops of all the High Plateaus and on the summits of Mts. Marvine and Terrill. It corresponds to the dry tundra of the arctic.

1. SOUTHERN DESERT ZONE

DESERT CANYONS OF WATER POCKET FLEXURE.—Although the upland near Fruita belongs to the piñon zone, the canyons and washes here exhibit a more southern flora, representing the northern extension of the Lower Sonoran. This may be accounted for partly by their lower altitude, but it is due also to the fact that the water courses of the Colorado River system must serve as the highways of migration for the Lower Sonoran flora, since overland passage to the north is blocked by the high plateaus in Arizona. In some respects these canyons in the Capitol Reef resemble those in Zion National Park. Both are carved into the Vermilion and White Cliff sandstones; Zion Canyon is farther south and about 2000 feet lower, and so is warmer and has a longer growing season. In spite of this its climate is less arid than that of the Water Pocket canyons, perhaps because it has been eroded deeper and so is more shaded. However, since the Fremont Valley (fig. 2) is farther from the centers of distribution of Lower Sonoran species, it has fewer representatives from that zone.

Most of the canyons in the Water Pocket Flexure are deep and very narrow. All of them except the Fremont itself and several of its larger tributaries are usually dry. Floodplain studies therefore were confined to the lower end of Spring Canyon, to Pleasant Creek, and to the Fremont River. The last is heavily charged with red silt, but its current is so rapid that most of this is carried on to the Colo-

rado River and only the heavier sand and gravel are deposited, except in a few places behind bars or levees.

Mats of *Halerpestes cymbalaria* seem to have been the first pioneers on the wet sand of floodplains. *Ranunculus* spp. and *Muhlenbergia asperifolia* soon follow. On the dry sand of levees and small dunes, *Abronia elliptica* and *Franseria acanthicarpa* are succeeded by *Salsola pestifer*, *Cenchrus pauciflora*, and *Atriplex canescens*. *Salix lasiandra* is the most common pioneer streamside shrub. *Salix exigua* and other willows may accompany it. *Asclepias incarnata*, *Melilotus alba*, *Cleome lutea*, *Stanleya integrifolia*, *Artemisia tridentata*, and *Chrysothamnus graveolens* grow quite tall along the streams. *Clematis ligusticifolia* festoons many of the streamside shrubs. Each zone seems to have its own species of rose. Here it is *Rosa puberulenta*. In sunny places on sandy floodplains *Populus fremontii* follows the willows, although it is sometimes the pioneer tree, as on the floodplain of Pleasant Creek in the desert below Notom (fig. 1). Above the Water Pocket Flexure along the same stream *Populus trichocarpa* and escapes of *P. alba* are common.

On shadier floodplains, *Acer interior* replaces the Fremont cottonwood. With it is *Populus angustifolia* and sometimes *Toxicodendron rydbergii*. In the still denser shade of narrow canyons *Cornus stolonifera* and *Betula fontinalis* grow on the banks of the streams. These have come down stream from a zone or two above. *Fraxinus anomala* and *Rhus utahensis* usually occur abundantly back from the water's edge on the higher floodplain.

As the canyon is widened and the floodplain built up, the former streamside zone becomes more arid, both as to soil and to atmosphere. Its vegetation then retrogresses to the desert formation which is the climax of the region. So on the higher grounds of wide floodplains various cacti (*Opuntia* spp., *Echinocactus*, *Echinocereus*), *Ephedra viridis*, *Yucca harrimaniae*, *Lepargyrea rotundifolia*, *Wyethia scabra*, *Coleosanthus microphyllus*, *Chrysopsis* spp., and the desert grasses *Hilaria jamesii* and *Sitanion hystrix* are typical. Wherever the dry sand is piled up into dunes, *Abronia*s and their associates come in.

GRAVEL WASHES.—In the gravel washes where the soil is moister, deeper, and more level than that on the uplands, the vegetation presents a more desert-like aspect than that of the ridges above.



FIG. 2



FIG. 3

FIGS. 2, 3.—Fig. 2 (above), Fremont valley above Fruita. The alluvial soil is irrigated for cultivation. The southern desert formation occupies the lower slopes; the cedar-piñon woodland, the upper slopes. Fig. 3 (below), through the arch of the Wayne County (Utah) natural bridge. Cedar-piñon climax on talus of White Cliff sandstone.

Although they are usually dry, a cloudburst every few years is sufficient to sweep the washes clean of all vegetation. Shrubs and herbs may return in the time intervening between wet years, but not such slow growing forms as cedars and piñons. In the draws are *Cleome lutea*, *Polygala subspinoso* (?), *Lavauxia howardii*, *Sphaeralcea grossulariaefolia*, *Phacelia corrugata*, *Delphinium scaposum*, *Astragalus thompsonae*, *Chamaesyce fendleri*, *Asclepias cryptoceras*, *Eriogonum alatum*, and several cacti. Shrubby forms such as *Ephedra viridis*, *Cowania stansburiana*, *Odostemon fremontii*, *Amelanchier utahensis*, *Pleiocanthus spinosus*, *Rhus utahensis*, *Artemisia tridentata*, and *Chrysothamnus graveolens* follow the herbs. In shady places *Quamoclidion froebelii*, *Pentstemon caespitosus*, *Datura meteloides*, *Asclepias labriformis*, *Artemisia filifolia*, *Jonesiella asclepiadoides*, and others are found instead.

ROCK CANYONS.—Higher upstream the sandy deposits are limited to deltas or bars at the mouths of side canyons. Vegetation on the rock floors differs from that of the floodplains. In shady places *Odostemon fremontii* is common. *Juniperus utahensis*, *Pinus edulis*, and *Cercocarpus intricatus* are occasionally seen on the ledges of the canyon walls. On sunny rocks *Ephedra torreyana*, *Lepargyrea rotundifolia*, and a shrubby *Eriogonum* appear. Near a spring at the mouth of a side canyon is a clump of *Celtis rugulosa*.

Narrow canyons develop more mesophytic vegetation. Both western yellow pine and Douglas fir, with a rank undergrowth of *Odostemon repens*, *Ceanothus fendleri*, *Amelanchier utahensis*, *Pentstemon eastwoodii* var. *undosus*, *Selaginella mutica*, and *Phlox austromontana* are found. A colony of *Pinus ponderosa* accompanied by a thicket of *Arctostaphylos platyphylla* occurs on a north-facing sandstone cliff in the lower piñon-cedar zone. The presence of crustose and foliose lichens and xerophytic mosses on white sandstone indicates that erosion is slow.

2. PIÑON ZONE (SOUTHERN SEMIDESERT ZONE)

The nut pine-cedar association is the climax of the southern semidesert zone (fig. 3). It is reached mainly through a xerarch or occasionally through an alkali succession, for there are no ponds or lakes, and the stream beds at this level are dry except when it rains. Stabil-

ity and depth of soil are the main factors in the xerarch succession in this zone, for even in the climax pine-cedar woodland the plants are spaced so far apart that light and moisture conditions are not very different from those of the pioneer stages. The tree stages, however, do require a somewhat deeper soil. The type of soil does not seem to be important, for this southern semidesert formation occurs on white sands, red stony clays, and on heterogeneous soils derived from conglomerates containing huge black lava boulders. *Acarospora* and other crustose lichens initiate the succession on the lava. They are followed by *Parmelia* spp., and the moss *Tortula muralis*. Shale and sandstone weather so rapidly that these earliest stages are usually omitted on them. Crevice plants such as *Selaginella selaginella* are more commonly the first pioneers on the sandstone ledges. In the deeper crevices almost any species of the piñon-cedar association, including the dominant trees themselves, may be found. Pioneer crevice herbs aid in enlarging the small pockets and accumulating sufficient soil for shrubs and eventually for trees. The wind, too, is an important agent in this succession, for it honeycombs the sandstone walls (fig. 3) and then piles the sand on the ledges in the form of dunes. On these dunes the pioneers are of a different sort. They must have root systems which can aid in binding the shifting sand or which can endure a fluctuating soil level. *Abronia elliptica*, *Franseria acanthicarpa*, *Salsola pestifer*, *Arenaria aculeata*, *Townsendia arizonica*, *Hilaria jamesii*, *Erigeron argentatus*, *Gilia dixonae* Nels., *Phlox canescens*, and several species of cacti are dune pioneers. *Odostemon fremontii* and *Rhus utahensis* represent the shrub stage. The trees are less common on dunes than in large crevices or in rocky soils where anchorage is better.

The herbs and shrubs are much more abundant and the trees are closer together, larger, and more symmetrical on coarse rocky soils than on the wind-polished sandstone plateaus (fig. 3). The dominant herbs are *Sphaeralcea grossulariaefolia*, *Lygodesmia juncea*, *Calochortus nuttallii*, *Lavauxia brachycarpa*, *Stipa speciosa*, *Aristida fendleriana*, *Andropogon scoparius*, *Artemisia wrightii*, *Pentstemon ophianthus*, *Pleiocanthus spinosus*, *Opuntia* spp., *Echinocactus xeranthemoides*, *Echinocereus triglochidiatus*, and *E. mojavensis*. The woodier forms include *Yucca harrimaniae*, *Artemisia tridentata*, *Chrysotham-*

nus graveolens, *Lepargyrea rotundifolia*, and *Amelanchier utahensis*. *Philadelphus microphyllus*, *Odostemon fremontii*, *Rhus utahensis*, and *Quamoclidion froebelii* are more common on shady slopes. These species perhaps precede the trees, but continue on with them in the richest piñon-cedar woodland.

STREAMSIDE VEGETATION IN PIÑON ZONE.—The permanent streams in this zone are often fringed merely with more luxuriant sagebrush and rabbit brush, but the narrow-leaf cottonwood seems to be the typical streamside species. It may be preceded by willows. *Rosa puberulenta* and *Rhus utahensis* accompany it. *Urtica breweri* is common on the floodplain of the Fremont River. *Acer interior* and *Betula fontinalis* replace *Populus angustifolia* in shaded places. *Picea excelsa* is seen along the streams in the upper limits of the zone.

3. ALKALI ASSOCIATION

On shaly soils alkali crusts may form, for drainage is poor and the salts are not leached out. As at Notom where the pH is 7.8 to 8.0, the piñon-cedar woodland is replaced indefinitely by a long-time temporary climax of *Atriplex confertifolia* and *Sarcobatus vermiculatus*, which may be introduced by *Distichlis spicata* on flats of alkaline mud along the stream. The alkali desert formation (fig. 1) covers the soil very scantily; vast stretches are plantless.

4. NORTHERN DESERT CLIMAX

Almost the entire Awapa Plateau, the west side of Aquarius Plateau, and the lower slopes of the Fish Lake Plateau are covered by the sagebrush formation. The successions here, too, are all xerarch, since there are no ponds, lakes, nor even streams. The lava rock shows the usual pioneer lichen and moss stages. Xerophytic herbs are first in the crevices. They are soon accompanied down at 7000 feet by cacti and yucca, but up at 9000 feet by *Gilia aggregata*, *Pentstemon strictus*, *Calochortus nuttallii*, *Eriogonum piperi*, a bright rose-colored *Opuntia*, and *Lupinus* spp. When the soil layer is deep enough, *Artemisia tridentata* and *Tetradymia canescens inermis* become dominant, but the herbs continue in the interspaces.

Swamps in the sagebrush zone between Richfield and Fish Lake are of the sedge type. Anderson Wash southeast of Sigurd is fringed

with *Salix* spp., *Acer negundo*, *Prunus melanocarpa*, and *Populus angustifolia*. If swamps and streams existed in the sagebrush desert on the Awapa Plateau they would probably have similar vegetation.

5. NORTHERN SEMIDESERT

The cedar-mountain mahogany climax occurs on the middle slopes of the west face of the Fish Lake Plateau from about 8000 feet altitude to over 9000 feet on south facing walls. Piñons are dropping out and with them the southern semidesert shrubs, *Lepargyrea rotundifolia*, *Rhus utahensis*, *Fallugia paradoxa*, and *Cowania neomexicana*. Instead of these, *Juniperus utahensis* is accompanied by *Cercocarpus parvifolius*, *C. ledifolius*, *Juniperus scopulorum*, and *Quercus utahensis*, in a mixed woodland in which grow *Artemisia tridentata*, *Purshia tridentata*, *Prunus melanocarpa*, *Amelanchier oreophila*, *Sericotheca diffusa*, *S. microphylla* (?), *Eriogonum effusum*, *Pachystima myrsinites*, and species of *Symphoricarpos* with a rich herbaceous complement of *Lupinus*, species of *Eriogonum*, *Castilleja*, *Pentstemon*, *Solidago bigelovii*, *Gutierrezia*, *Artemisia frigida*, *Agropyron spicatum*, and others. In the lower part of this mountain mahogany zone are *Yucca* and *Opuntia*.

The distribution of these four desert formations seems to be determined by several factors. Temperature may limit the range of the southern desert species. They are most common below 6000 feet in the Fremont Basin. Those requiring long hot summers and mild winters have not yet migrated to the 9000 foot crest of the Awapa Plateau, and so are not included in the desert flora on the Great Basin side of the divide. The southern semidesert occurs in a rather definite belt between 6000 and 7500 feet on the sandstone plateaus, but on lava soils the sagebrush formation occupies this level, and the cedar-piñon zone is pushed up to even 9000 feet in some places. Hence competition, especially with *Artemisia tridentata*, seems to be more important than temperature in limiting the range of cedars and piñons, for prostrate forms of both were found in the subalpine zone on Thousand Lake Mt.

6. PINUS PONDEROSA CLIMAX

In the western yellow pine zone, studies were made of the upland xerarch succession and of the streamside vegetation. The only hy-

drarch succession found was on the tension line between this and the aspen zone. Since the climate in depressions is cooler than that on adjacent ridges, it is included in the account of the aspen rather than in that of the western yellow pine zone.

TIDESTROM's map (6) shows *Pinus ponderosa* between 7000 and 9000 feet. SAMPSON (5), however, gives its range as 6200 to 7600 feet. On the Aquarius Plateau the main forest lies between 7500 and 9000 feet on the east face and 7000 and 8500 feet on the north face, with isolated colonies as low as 5600 feet. The western yellow pines on the east spurs of Thousand Lake Mt. are at an altitude of about 8000 feet. *Pinus ponderosa* seems to occur here on flat areas of both residual and aeolian sands and on steep slopes of glacial drift. Sandy slopes may be too dry and flat clays too poorly drained for it.

XERARCH SUCCESSION.—On resistant rock, crustose lichens form the initial stages. These are followed by *Parmelia* and other foliose forms, and by xerophytic mosses. After these pioneers, together with agents of erosion, have disintegrated the rock, xerophytic herbs such as *Antennaria aprica*, *Pediocactus simpsonii*, *Opuntia fragilis* (and other *Opuntia* spp. in the lower parts of the zone), *Eriogonum racemosum*, *Bouteloua gracilis*, *Sitanion hystris*, and *Oreocarya suffruticosa* come in on the new soil. In sandy places *Abronia elliptica*, *Phlox stansburyi*, and *Pentstemon arenicola* are common pioneers. *Pentstemon cyananthus* (?), *Gilia aggregata*, *Linum lewisii*, and *Oreocarya argentea* follow them. *Rosa* spp. are common in loose sand, and *Cercocarpus intricatus* in crevices of sandstone cliffs. In the lower part of the zone *Yucca*, several cacti, and *Pleiocanthus spinosus*, found in the piñon zone, are common pioneers, especially on rocky soils.

Purshia tridentata, *Ceanothus velutinus*, *C. fendleri*, *Amelanchier alnifolia*, *Sambucus melanocarpa*, *Cercocarpus montanus*, *Symphoricarpos oreophilus*, and species of *Ribes*, *Grossularia*, and *Rosa* are fairly common representatives in the shrub stage throughout the zone. *Artemisia tridentata* and *Chrysothamnus graveolens* come in on deeper soils. In the lower part of the zone, *Cowania neomexicana* and *Fallugia paradoxa* extend up from the piñon zone; and in the upper part are such shrubs as *Odostemon repens*, *Arctostaphylos uva-ursi*, and *Prunus melanocarpa*, all common to the aspen zone. Thickets of

Arctostaphylos platyphylla or of *Quercus utahensis* are sometimes seen on sunny slopes. Occasional specimens of *Pinus edulis* or of *Juniperus utahensis* grow taller and straighter here than in their own zone, another indication that competition may be a limiting factor determining their range. *Juniperus scopulorum* is frequent as an understory tree in the western yellow pine forest. Seedlings of *Picea pungens* occasionally come up on open hillsides. The western yellow pine itself comes in when the soil is deep enough and is well drained. It reproduces well, as is shown by the large number (38) of vigorous seedlings in a 10 meter quadrat which had been protected from grazing for five years. In a quadrat of equal size and similar situation but grazed were only nine pine seedlings. Overgrazing leads to soil erosion, and *Pinus ponderosa* seems to require deep soil.

Since this forest is an open one, many of the pioneer forms continue as undergrowth in the climax stage. Certain species, however, are especially characteristic under the pines. *Peltigera canina* grows on the fallen needles. *Phlox austromontana*, a prostrate, awl-leaved, mat-type species with white to clear pink flowers, is perhaps the most conspicuous herb. *Tithymalus luridus*, *Pseudocymopterus montanus*, *Antennaria aprica*, and *Erigeron vetensis* are also common. *Poa pratensis* and *Agropyron spicatum* are dominant grasses. *Clematis pseudoalpina* grows at the bases of tree trunks. On the north face of Aquarius Plateau *Castilleja linariaefolia*, *Geranium richardsonii*, *Hymenoxys odorata*, *Lupinus lepidus*, and a red *Pentstemon* are abundant. *Senecio* and *Hymenoxys* are considered by the rangers as indicative of overgrazing. In places the sheep have practically eliminated the shrubs in the pine forest.

STREAMSIDE VEGETATION OF PINUS PONDEROSA ZONE.—*Salix subcoerulea* and *S. bebbiana* fringe the streams at 8000 feet. The first tree on the floodplain is *Populus angustifolia*. *Betula fontinalis* is a close second. With them on wet banks are gooseberry, elderberry, currant, and rose, accompanied by *Veronica arvensis*, *Juncus* spp., *Artemisia racemosa*, *Montia chamissoi*, *Equisetum hiemale*, mosses, and liverworts. Growing in the stream among rocks are *Cardamine infausta* and *Catabrosa aquatica*. In the next belt back from the stream is *Picea pungens* with *Juniperus scopulorum* and *J. sibirica*. Among these conifers are *Smilacina stellata*, *Geranium richardsonii*,

Arenaria eastwoodii, and *Wyethia mollis*. The willows and cottonwoods seem to be limited to the stream's edge, but the blue spruce has a wider range.

OAK THICKETS.—SAMPSON (5) points out the oak as an ecological equivalent of *Pinus ponderosa* which is capable of replacing the pine. Usually the sheep browse the oak so closely that it remains a low shrub. On steep, rocky, more inaccessible slopes it attains a height of 7-10 feet. Typical pine forest pioneers seem to precede *Quercus utahensis* and a typical pine undergrowth accompanies it: *Odostemon repens*, *Castilleja linariaefolia*, *Phlox austromontana*, *Ceanothus fendleri*, and seedlings of *Juniperus scopulorum*. On Aquarius Plateau the oak association seems to be a pioneer tree stage which precedes the climax western yellow pine forest, and apparently is not an ecological equivalent of it. On the west face of Fish Lake Plateau the oak appears on ridges in the upper part of the mountain mahogany zone at the same level where aspens are first seen in the ravines.

MANZANITA.—*Arctostaphylos platyphylla* also forms only small local colonies here, and so can scarcely be considered as anywhere replacing the pine as a climax form. Instead it seems to occur as a subclimax stage in the xerarch succession to the pine forest.

FOX-TAIL PINE.—Although classified by TIDESTROM as belonging in the aspen-spruce zone, *Pinus aristata* is found here only in two small colonies in the western yellow pine zone on the north face of Aquarius Plateau. In such a situation it may be a relict of the Pleistocene.

7. MONTANE ZONE

This zone is best exhibited on north and east facing slopes in a belt extending from 8700 to 9500 feet in altitude. The aspen forms extensive groves. The Douglas fir is not found in as pure stands as the aspen; it seems to be restricted to the steeper, more exposed slopes, rocky ridges, talus slides, etc., while the aspen occupies morainic lacustrine, or alluvial deposits where the soil is deeper and moist. In shaded mesophytic canyons and about springs on slopes, aspens descend to 7500 feet, and perhaps occasionally lower. The lowest altitude recorded for Douglas fir in this region is about 6000 feet. On the other hand, both species occur mixed with Engelmann spruce and subalpine fir in the forests below the lava caps on all three of the

plateaus. There are dwarf aspens as high as 10,700 feet. As a rule, however, they do not reach the summits.

Like the sagebrush, the aspen takes the deeper, moister soils of pockets and shady north faces in the lower part of its range, but comes out on the ridges in the upper stretches, for below, the ridges are too dry, and above, the summers in the pockets are too short.

The Douglas fir association seems usually to climax a xerarch succession, but both xerarch and hydrarch series may terminate in the aspen association.

XERARCH SUCCESSION TO CLIMAX MONTANE FOREST.—Wherever resistant rock is found, the earliest stages are the usual crustose lichens, *Acarospora bella*, *A. spp.*, *Caloplaca spp.*, and *Candelariella vitellina*, followed by *Parmelia molliuscula*, *P. conspersa*, and the moss *Tortula muralis*. The succession on soil begins with xerophytic herbs, the most conspicuous of which are *Pleiocanthus spinosus*, *Artemisia frigida*, *Chaenactis douglasii*, and *Pediocactus simpsonii*, this last a cactus which seems to be limited to moderately high altitudes (8700–9800 feet) and to thin rocky soils. Other xerophytes accompany these pioneers later and eventually crowd them out: *Erigeron bloomeri*, *E. flagellaris*, *Antennaria aprica*, *Eriogonum racemosum*, *E. jamesii*, *Castilleja exilis* and other species, *Lupinus argenteus*, *L. alpestris*, *Sitanion hystris*, *Stipa comata intermedia*, *Koeleria cristata*, *Gilia aggregata*, *Phlox cortezana*, *Senecio multilobatus*, *S. mutabilis*, and others. These herbaceous xerophytes form the present cover on the dry knolls of the spurs projecting from the façades of the plateaus. Below them is a shrub zone which dovetails into the aspen grove or Douglas fir forest, as the case may be. The xerophytic shrub pioneers are common to the pine forest below. They include *Tetradymia canescens inermis*, *Artemisia tridentata*, *Purshia tridentata*, species of *Chrysothamnus*, *Amelanchier alnifolia*, *Sambucus melanocarpa*, *Rosa fendleri*, *Ceanothus fendleri*, *Ribes leptanthum*, *R. viscosissimum* (?), and *Prunus melanocarpa*. Just preceding the aspen is *Symphoricarpos oreophilus*, which remains as the dominant undershrub in the aspen grove. *Lepargyrea argentea*, *Odostemon repens*, *Lonicera involucrata*, *Arctostaphylos uva-ursi*, and *Pachystima myrsinites* form the undergrowth in the upper parts of the zone.

No doubt the aspen first establishes itself in any given place by

seeds; but the young aspens seen are practically always adventitious shoots which seem gradually to close in on these dry hilltop meadows until at last the ridge is completely covered by them. In these pure stands the shade is dense in summer, so the soil is moister than in the preceding stages. Consequently a new association of herbs replaces those of the dry meadow. *Geranium richardsonii*, *Castilleja lauta*, *C. arcuata* (?), *Aquilegia coerulea* and its variety *albiflora*, *Arabis drummondii*, *Phacelia sericea*, *Achillea lanulosa*, *Microseris* spp., *Fragaria glauca*, *Senecio atratus*, *Vicia americana*, and a *Delphinium* are found. In many of the upper aspen groves there is a ground cover consisting of an almost pure stand of *Lathyrus leucanthus*. *Odostemon repens* and *Pseudocymopterus montanus* are also common in the high aspen groves.

In wide areas on these plateaus are absolutely pure stands of aspen, the trunks often reaching 18 inches in diameter. On some slopes seedlings of Douglas fir, white fir, blue spruce, and (higher up) sub-alpine fir and Engelmann spruce are abundant under the aspens. In these mixed stands the aspens are the largest and dominant trees. This may be due to their more rapid growth, to their greater resistance to fire, or to their general freedom from timbering.

The Douglas fir never stands alone, but it dominates certain rocky slopes. The stages leading to this mixed Douglas fir forest are in general the same as those preceding the aspen, but not so rich in species. Since the Douglas fir succession is more apt to take place on a rocky slope, the pioneers consist of lichens and mosses on the rock faces with crevice plants between them.

The common shrubs are *Odostemon repens*, *Amelanchier alnifolia*, *Ribes viscosissimum*, *Ceanothus fendleri*, *Sambucus melanocarpa*, *Artemisia frigida*, *Symphoricarpos oreophilus*, *Arctostaphylos uva-ursi*, and *Pachystima myrsinites*. This succession differs from that leading to the aspen in that pioneer trees (*Cercocarpus montanus*, *C. ledifolius*, *Picea pungens*, *Pinus edulis*, *Juniperus scopulorum*) sometimes precede the climax forest. The blue spruce, which is often thought of as a streamside tree, is common here on dry rocky slopes with the Douglas fir. A forest island of *Picea pungens* in the midst of a dry meadow of cactus, sagebrush, etc., was found on a lava ridge at 9850 feet.

The shade under Douglas firs and other conifers is denser than that formed by the aspens; hence the ground cover is much less luxuriant. Most of the shrubs disappear as the Douglas fir grows up. *Odotemon repens*, *Juniperus sibirica*, *Symphoricarpos oreophilus*, and *Rosa pyrifera* endure the shade. *Lathyrus leucanthus*, *Pseudocymopterus montanus*, *Poa fendleri*, *Festuca ovina*, *Aquilegia flavescens*, *A. coerulea albiflora*, *Oxytropis deflexa*, and *Fragaria bracteata* are herbs of the Douglas fir forest. On the whole, the Douglas firs form only medium sized trees in this area. Specimens up to 30 inches in diameter at 4 feet above the ground are sometimes seen.

HYDRARCH SUCCESSION TO CLIMAX MONTANE FOREST.—The hydrarch succession may be found in ponds or in spring swamps which are located where ground water issues from the lava talus above the glacial clay. The soil of these spring banks was the most acidic of any of the samples tested, its pH varying from 6.4 to 6.6. The streamlets are fringed with a lush vegetation consisting of hydrophytic mosses (*Philonotis fontana*, *Aulacomnium palustre*, etc.) and the herbs *Mimulus guttatus*, *Aconitum columbianum*, *Habenaria elegans*, *H. unalaskensis*, *Galium boreale*, *Sidalcea candida*, *Hypericum formosum*, *H. scouleri*, *Polemonium viscosissimum*, *Thermopsis montana*, *Carex festiva*, *Juncus saximontanus*, *J. ballicus*, *Chamaenerion angustifolium*, *Veronica alpina*, *Epilobium ovalifolium*, *Geranium richardsonii*, and *Mertensia pratensis*. The pioneer shrubs are *Salix subcoerulea*, *S. bebbiana*, and other willows; they are followed by *Rosa woodsii* and *Lonicera involucrata*. Blue spruce is the pioneer tree in wet soil. Both aspens and Douglas fir seedlings occur on these spring banks, but the former are more common.

There are few aquatics in the deeper lakes such as Fish Lake, for their water is too cold. A gelatinous alga, *Chara*, *Myriophyllum spicatum*, and species of *Potamogeton* represent the submerged stage. *Batrachium trichophyllum*, *B. grayanum*, *Polygonum amphibium*, and *Hippuris vulgaris* surround the central zone of *Potamogeton americanus* in shallow lakes. These amphibious species are usually succeeded by a wet meadow which is often introduced by an almost pure stand of *Eleocharis acicularis*. *Roripa sinuata* and a small *Ranunculus* are sometimes first. Next on flat shores come *Eleocharis palustris*, *Juncus ballicus*, *Alopecurus aequalis*, *Halerpestes cymbalaria*, and

Myosurus aristatus—a small plant usually found on alkali mud at 4000 to 5000 feet in the Great Basin, and seemingly out of place on the shores of mountain lakes at 9700 feet. Next on the moist mud comes a zone of *Rumex mexicanus* with mats of *Taraxia breviflora*. A sedge meadow follows with *Phleum alpinum*, *Deschampsia caespitosa*, *Poa ampla*, *Agropyron tenerum*, *Stipa columbiana*, *Hordeum nodosum*, *Epilobium adenocaulon*, *Thermopsis montana*, *Antennaria microphylla*, *Arnica ocreata*, and species of lupine mixed with the numerous species of *Carex*.

Higher up is a drier meadow of *Dasiophora fruticosa*, *Pentstemon procerus*, *Artemisia cana*, *A. trifida*, *Achillea lanulosa*, *Pedicularis parryi*, *Potentilla pulcherrima* (?), *P. propinqua*, *Rosa pyrifera*, etc. Where the shores are steep and rocky instead of flat and muddy, narrow amphibious zones may be followed immediately by a fringe of willows or even of aspens.

STREAMSIDE VEGETATION.—In the open, swampy meadows occur along pre-erosion streams. Here hydrophytic sedges, mosses, and rushes are accompanied by clumps of willows, colonies of *Iris missouriensis*, *Carex nebraskensis*, *C. lanuginosa*, *Koeleria cristata*, *Oryzopsis hymenoides*, *Sisyrinchium angustifolium*, *Valeriana edulis*, and *Equisetum hiemale* followed by seedlings of blue spruce and later by aspen. In the higher places *Castilleja exilis*, *Agropyron tenerum*, *Aira caespitosa*, *Potentilla pennsylvanica*, *Aplopappus uniflora*, *Antennaria microphylla*, *Hypericum formosum*, rose, currant, and gooseberry come in.

Where the pre-erosion streams flow through the forest instead of a meadow their vegetation is similar to that of the spring banks. Among the rocks in forest streams grow *Cardamine infausta*, *C. cordifolia*, *Mimulus guttatus*, and *Epilobium ovatifolium*. *Aulacomnium palustre*, *Philonotis fontana*, *Conocephalum* sp., and *Marchantia* sp. border the streams. Among them are tufts of *Moneses uniflora*, *Pyrola chlorantha*, *Saxifraga rhomboidea*, *Smilacina stellata*—mostly representatives of zones higher up which are adapted to the cool water of these mountain streams. Wherever there are openings in the forest the willow fringe is seen, usually *Salix subcoerulea* and *S. bebbiana*. *Alnus tenuifolia* may be with them. Blue spruce seems to be a universal streamside tree of this zone, both in the open and in

the forest. With it are *Filix fragilis*, *Galium boreale*, *Phacelia idahoensis*, *Geranium richardsonii*, *Aconitum columbianum*, *Delphinium subalpinum*, *Smilacina stellata*, *Pyrola asarifolia*, *Veronica wormskjoldii*, *Epilobium adenocaulon*, *Phleum alpinum*, *Hypericum formosum*, *H. scouleri*, *Castilleja lauta*, *Polemonium foliosissimum*, *Habenaria elegans*, and *H. unalaskensis*.

In the few places where erosion has begun *Equisetum hiemale* is common on clay or drift banks above the line of present stream action. On new soils of small floodplains mats of *Halerpestes cymbalaria* are first; then willows, alders, and blue spruces occupy the stream deposits. Back farther on drier flats are raspberry, gooseberry, currant, rose, and sometimes *Juniperus sibirica* with *Poa canadensis*, *Fragaria bracteata*, *Potentilla glaucophylla*, *Phleum alpinum*, *Mertensia pratensis*, *Viola nephrophylla*, dandelions, and yarrow. Aspen comes in on the older floodplain accompanied by the climax shrubs such as *Symphoricarpos oreophilus*, *S. longiflorus*, *S. racemosus*, *Odostemon repens*, and the herbs of the aspen stage.

MONTANE CLIMAX FOREST.—The fact that aspen terminates both xerarch and hydrarch successions might seem to indicate that this tree is the true climax here. Its edaphic distribution would also class it as more mesophytic than *Pseudotsuga*. Yet the aspen does not seem to have a well defined undergrowth. Possibly the inconstant character of its undergrowth indicates that the aspen is not a true climax, as has been suggested by some, but a long-time temporary climax, as others contend. Perhaps it may be merely a stage in a secondary succession following fire, as some of the rangers think; but there were few signs of past burns. The aspen may be found succeeding itself, forming dense pure stands. It does so, however, by means of adventitious shoots, not by seeds germinated in its own shade. The aspen may be seen also sheltering seedlings of Douglas fir, or it may come in simultaneously with Douglas fir, or even after it. Both trees extend up into the Engelmann spruce zone; but the aspen is far more abundant than is the Douglas fir. The latter extends lower into the piñon zone than does the aspen, so it must be more tolerant of dry climate. The aspen is clearly more advanced as to soil requirements. On the other hand, aspen seedlings are more light-tolerant; but it colonizes mostly by means of adventitious shoots, and

these do well in shade. Thus this species, like the redwood, is able to maintain itself in conditions of extreme mesophytism although it ranks as a pioneer with respect to its light tolerance. The question whether the aspen or the Douglas fir is the true climax tree of this zone or whether they are ecological equivalents is still an open one.

8. SUBALPINE FOREST ZONE

Overlapping the upper 500–1000 feet of the montane forest, and reaching up to the summits is the subalpine forest. This zone, extending in the main from 9500 to at least 11,000 feet, is characterized by low annual temperatures, a moderate amount of moisture, a short growing season, and high winds. Snow falls as late as June and remains well into July, and the next cold season begins again with snow as early as the last of August.

Without doubt the dominant tree of this association is the Engelmann spruce. It extends from altitudes of 9000 feet at the bases of north facing canyon slopes up to the summits of the plateaus. From 9500 feet up it is the most abundant tree species, and in certain situations the only one. It has unfortunately fallen prey to the ax and the beetle; but tall, straight specimens with trunks 4 feet in diameter are still not uncommon in the dense forest belt just below the lava caps of the plateaus. On the summits and on the rock ridges, where the soil is thin and the wind is strong, it is of course stunted and gnarled; in such places it occurs only in small forest islands.

From 9500 feet up to the base of the lava cap, the Engelmann spruce is accompanied as usual by *Abies lasiocarpa*. The firs here have a narrower range than have the spruces, for neither do they extend as low on the north facing slopes nor do they reach the plateau summits. On south faces their range is from 9800 to about 10,700 feet, the highest altitude noted here for the subalpine fir. The altitudinal limits of this timberline tree seem to be restricted by edaphic rather than by climatic conditions; for wherever the soil is deep, as on the moraines or around alpine lakes, the fir is found. But on the thin, rocky residual lava soils on the summits, the Engelmann spruce stands alone. Throughout the zone the fir is only a subordinate species.

The aspen and the Douglas fir of the montane forest, which are

thoroughly mixed with the spruce and the fir in the lower part of the zone, thin out above. At 10,700 feet the last dwarfed and gnarled aspens were seen just leafing out on June 21 in 1932. Ranger Peterson of Elkhörn Ranger Station reported some limber pines on the summit of Thousand Lake Mt., but I did not find them. At 9800 feet are prostrate specimens of piñon and cedar 1 foot or so in diameter, growing with Douglas fir, aspen, Engelmann spruce, and subalpine fir. TIDESTROM (6) gives 6000 feet as the altitudinal limit of the piñon and RYDBERG (4) locates it at about 8000 feet. Only the yellow pine is lacking at this site to make a complete series.

The subalpine zone is well represented on all three plateaus. Both xerarch and hydrarch successions were found.

XERARCH SUCCESSION TO SUBALPINE CLIMAX.—Xerarch successions are best seen on talus slides and on lava cliffs. On the bare rock are four or five species of crustose lichens: *Acarospora bella*, a black *Acarospora*, *Caloplaca* spp., and *Candelariella vitellina*; semifoliose species such as *Lecanora rubina* and *L. saxicola* follow the xerophytic mosses such as *Tortula muralis* and possibly *Hedwigia*. *Selaginella watsoni* comes in in crevices and on the moss cushions. These early pioneers are followed on rock by the same herbs which introduce the succession on glacial soils and in crevices. On vertical lava walls, *Monardella odoratissima* is nearly always found wherever a little soil has collected. *Polemonium confertum*, *P. pulcherrimum*, *Draba aurea*, *Filix fragilis*, and *Oxyria digyna* are also found in rock crevices in this zone. On deeper soil which is sheltered from the wind, *Mertensia pratensis*, *Polemonium pulcherrimum*, *Aquilegia coerulea*, *Drymocallis fissa*, *Eriogonum subalpinum*, *Erigeron flagellaris*, *Antennaria rosea*, *Phacelia sericea*, *Synthyris laciniata*, *Anemone globosa*, *Sieversia ciliata*, *S. turbinata*, and *Potentilla glaucophylla* are common. In moist crevices *Primula parryi* grows luxuriantly. Where grazing is heavy *Achillea lanulosa*, *Taraxacum officinale*, *Hymenoxys richardsonii*, and *Dugaldia hoopesii* come in. Shrubs follow the herbs. *Dasiophora fruticosa*, *Sambucus microbotrys*, *Ribes lentum*, *Rubus strigosus*, and *Juniperus sibirica* are most frequent; but *Ribes cereum*, *Shepherdia canadensis*, *Lonicera involucrata*, *Arctostaphylos uva-ursi*, *Pachystima myrsinites*, and *Odostemon repens* are also found, especially in the lower parts of the zone. In the shelter of boulders on the summits,

Juniperus sibirica and *Ribes lentum* present compact wind-carved thickets in the lee of which the Engelmann spruce starts. The spruce, too, is dwarfed and twisted. One specimen with a trunk 2 feet in diameter was only 18 feet tall. The spruce islands on the summits retain a border of the herbs and shrubs just listed.

Below the rim where the wind is checked the trees become tall and symmetrical. They form continuous forests which cast a shade so dense that the pioneer shrubs and herbs are eliminated. As undergrowth are *Arnica cordifolia*, which may be considered as an indicator of this association, *Saxifraga rhomboidea*, *S. arguta*, *Pyrola secunda*, *Pseudocymopterus montanus*, *Lathyrus leucanthus*, *Thalictrum megacarpum*, *Fragaria bracteata*, *Peltigera* sp., and a *Castilleja* which seemed to be the earliest species through the snow. A species of *Usnea* and *Letharia divaricata* sometimes festoon dead limbs of the spruce. The understory in the climax spruce-fir forest is very sparse, except where there are openings in the forest canopy, for not only is the shade too dense for most plants, but it prevents early thawing of the snow, so that the season is considerably shortened as compared with that of similar situations in the open. Fleshy fungi are frequently abundant on the humus in these forests. Such forms as *Morchella*, *Boletus*, *Clavaria*, and *Lycoperdon* are plentiful.

HYDRARCH SUCCESSION TO SUBALPINE CLIMAX.—Depressions in this zone such as ice-scoured basins, morainic hollows, or troughs dammed up against the lava wall by glacial deposits are occupied by lakes or meadows and surrounded by the subalpine forest. Whether the hydrarch succession attains a forest stage or terminates in the alpine meadow is a question. But whether the alpine meadow is a true climax or merely a long-time temporary climax, it seems to occupy all of the situations which ever have been hydrophytic. In some places the forest is bordered by a belt of Engelmann spruce seedlings which seem to be encroaching upon the meadow surrounding the lake; but usually there is a sharp line between the forest and the meadow, the latter occupying the sediments in the depressions and the former the rocky shores of the basins.

Numerous bodies of water varying from a few feet to a mile or so in diameter are found between 9500 and 10,000 feet. Those at lower altitudes are bordered by the subalpine forest on their north and

east facing shores, but by the montane forest on the south and west faces. In the higher, deeper, and consequently colder lakes there are no submerged or floating aquatics, but near the shores there may be a zone of rushes (*Juncus* spp.) followed by a zone of sedges (*Carex* spp.) in shallow water. In the free water of shallow ponds, however, grow *Hippuris vulgaris*, *Potamogeton americanus*, and *Polygonum amphibium*. Following the sedge zone on flat shores is a meadow of gentians (*G. heterosepala*, *G. plebeja*, and others), mosses (*Bryum capillare*, *Aulacomnium palustre*, *Climacium americanum*, *Mnium serratum*, etc.), and *Castilleja* spp., *Equisetum hiemale*, *Sagina saginoides*, *Arenaria sajanensis*, *Taraxia breviflora*, and species of *Antennaria*. One lake at the base of the Thousand Lake lava is surrounded by a slimy white mud on which grows *Leontodon scopulorum*, the dwarf dandelion with heads not more than a quarter of an inch in diameter, on scapes less than 1 inch tall.

On steep shores, which are more common, is a narrow fringe of willows at the water's edge. These are followed closely by subalpine shrubs, *Juniperus sibirica*, *Ribes roezli*, *R. niveum*, etc.; then by aspens with an undergrowth of *Fragaria bracteata*, *Geranium richardsonii*, etc.; and these in turn by the Engelmann spruce and the subalpine fir, which come almost to the water's edge, yet do not seem to occupy any zone which has been a part of the lake itself.

Some ponds are developing a sedge fen with a belt of *Zygadenus elegans* around it.

In the deep valleys, or even in only slight depressions on the tops of the plateaus, there develop alpine meadows which have the appearance of permanent features interrupting the forest and giving the landscape the parklike aspect of the Kaibab Plateau in Arizona.

STREAMSIDE VEGETATION IN SUBALPINE ZONE.—Most of the streams in this zone issue from snow banks or from ponds on the summit and are yet of the pre-erosion type. Increased soil moisture along their courses is the main alteration they make in the subalpine forest. Where they are wide enough they eliminate a band of trees through the forest, thus increasing the illumination at the herb level. Among the rocks in these streams are *Cardamine infausta*, *C. cordifolia*, and *Primula parryi*. On moist sunny banks is a rich growth of *Aconitum columbianum*, *Delphinium cockerellii*, *Mertensia pratensis*,

Allium brevistylum, *A. cernuum*, *Sium cicutaeifolium*, *Aquilegia coerulea*, *Arnica cordifolia*, and the mosses *Amblystegium serpens*, *Swartzia montana*, *Polytrichum juniperinum*, *Bryum schleicheri* (?), *Brachythecium idahense*, *Mnium serratum*, *Pohlia cruda*, and *Pohlia nutans*. Several species of *Castilleja* and *Lupinus* also occur. *Pentstemon whippleanus* is found along practically all streams in the subalpine forest but almost nowhere else.

When the streams flow through open meadows, they often have a willow fringe, *Salix subcoerulea*, *S. bebbiana*, and others. The meadows are in more level places than the forests, so the streams are more sluggish through them. In the wet mosses are *Viola macloskeyi* (?), *Gentiana heterosepala*, *G. plebeja*, *Parnassia parvifolia*, *Ranunculus inamoenus*, *R. calthaeiflorus*, *Moneses uniflora*, *Pyrola chlorantha*, *Carex engelmannii* and other herbs, and *Ribes cereum* and *R. lentum*.

No eroding banks nor floodplains were found along the streams in this zone.

CLIMAX STAGE OF SUBALPINE ZONE.—The montane forest is often described as the finest of the mountain forests. On these plateaus the western yellow pine climax, although more open, exceeds it in the size of the individual trees, and the subalpine forest exceeds it in both density and size of trees. Where it is protected from high winds, the Engelmann spruce forest gives the impression of greater mesophytism even than the aspen groves below it. Since the Aquarius is the largest of these plateaus, it is less affected by wind and so has more extensive areas of these fine forests. In the past 15 years, nine-tenths of the adult Engelmann spruces on Boulder Mt. have been destroyed by a bark beetle, *Dendroctonus engelmannii*. The young spruces are not attacked because they are too resinous. Those below the rim seem to have been bothered less than those on the summit. The moisture conditions may account for this difference, since more vigorous growth results in greater production of resin. Climatic cycles may also be a part of the complex, since a series of dry years would give the beetle the advantage while a wet series would enable the forest to combat it.

Since the Engelmann spruce is the sole tree species on the top of the plateau, the next step in the vegetational history is conditioned

by the question, Will the beetle wipe out the forest entirely? It has nearly succeeded on Boulder Mt. at least. Or, will young trees grow up rapidly enough to replace the old ones destroyed? The spruce bears cones while still young and resinous enough to ward off the beetle. Will these young trees remain immune until the beetle is starved out, or will they mature rapidly enough to keep it supplied with food? If the forest is destroyed, what next? Will the entire plateau top develop as a meadow? Or, will another subalpine tree replace the spruce? The subalpine fir is not bothered by this beetle, but it is only the subordinate tree of the subalpine forest here. It has not succeeded so far in establishing itself on the summit. Douglas fir reaches timber line elsewhere, but it, too, is more or less scarce here. The few aspens which have reached the summit are dwarfed and gnarled. Conditions are too hard for them. Elsewhere some forest successors are usually ready to replace the fallen species.

9. ALPINE MEADOWS

In the alpine and subalpine zones the depressions usually seem to give rise to a mesophytic meadow which may represent a climax alternating at such altitudes with the spruce forest, or it may represent simply a long-time temporary climax which will eventually give way to the spruce forest. As long as these areas are basins and valleys, they will have a colder and moister climate than the ridges adjoining them. Because of late-lying snows their growing season is shorter. Because of protection from wind their evaporation is less. Because of higher water-table their soil moisture is greater. And because of cold-air drainage into them their temperatures are lower. In short, their climate is not that of the neighboring forest. If every climate has its climax, we should not expect the same climax in these two situations.

Some of the same species found in these mountain meadows are typical also of snow bank vegetation. Around snow banks on slopes we get much the same climatic conditions—short season, low temperature, and high moisture. Plants found in such places must be tolerant of such conditions, although they may be unable to compete elsewhere with other species. Probably not until the depressions are filled so that their climate approaches that on the slopes

surrounding them will conditions allow the forest to replace the meadow.

The depressions on the summit have thinner soil and are shallow and therefore windier than those in the zone below. The dry alpine scrub association eventually supplants the wet meadow species in these places. Below the subalpine zone where the season is longer, the forest may replace the meadow. In both of these situations the mesophytic alpine meadow association is but a subclimax.

In this plateau region the typical meadow formation occurs in valleys and other depressions from 9000 to 11,000 feet and around snow banks on the summits. Small pre-erosion streams make their way through many of them. The alpine meadow here is apparently always reached through a hydrarch succession, which is one of the arguments for considering it but a temporary climax.

Deep water at such altitudes is too cold for vegetation, but in shallow water, rushes (*Eleocharis acicularis*, *Juncus filiformis*, *J. saximontana*), sedges (*Carex ebenea*, *C. siccata*, *C. variabilis*, and others), and aquatic mosses (*Amblystegium riparium* vars. *fluilans* and *longifolium*, *Crataneuron filicinum*, *Bryum caespiticium*, *Drepanocladus aduncus intermedius*, *D. uncinatus*, *Mnium affine rugicum*, and *Philonotis fontana*) appear as the hydrophytic pioneers. Some meadows are occupied by an almost solid stand of this association. Such a spongy turf seems to develop most frequently in silty meadows in this zone. Streams running through the sedge fen are bordered by *Salix pseudomyrsinites aequalis* (?), *S. subcoerulea*, and other willows.

Rocky floors of valleys do not seem to be favorable for the formation of a sedge turf. Instead they usually develop the typical mountain meadow association. Summit Valley at 9500 feet is a good example. Here the pioneer aquatic rushes and sedges are followed first by *Caltha rotundifolia*, which often pushes its flower stalks through the snow. Soon after it comes *Polygonum bistortoides* and *Pedicularis groenlandica* or its variety *surrecta*. These three species and *Phleum alpinum* are always to be found in the mountain meadows of this region. *Deschampsia caespitosa*, *Poa longiligula*, *Gentiana heterosepala*, *G. plebeja*, *G. calycosa*, and *G. affinis* may also be found in the wet meadow zone. Next comes in a somewhat drier belt of such

forms as *Zygadenus elegans*, *Ranunculus calthaeiflorus*, *Clementsia rhodantha*, *Dodecatheon pauciflorum*, *Veronica wormskjoldii*, *Saxifraga rhomboidea*, *Sieversia brevifolia* (?), *S. ciliata*, *Trifolium rydbergii*, *Poa sandbergii*, *Thermopsis montana*, *Potentilla effusum*, *P. concinna*, *P. monspeliensis*, *Lupinus parviflorus*, *Antennaria aprica*, *A. parvifolia*, *Senecio petrophilus*, and several species of *Castilleja* (*C. lauta*, *C. arcuata*, and others). This stage probably represents the climax of this series. In badly overgrazed meadows the climax forms may be partly or wholly replaced by such weedy species as *Hymenoxys richardsonii*, *Antennaria aprica*, *Androsace diffusa*, *Orthocarpa lutea*, yarrow, and dandelion. Along the streams are *Delphinium subalpinum*, *Aconitum columbianum*, *Mimulus guttatus*, *Cardamine infausta*, and sometimes willows.

There is usually a transition belt separating this meadow from the spruce forest. It is dominated by *Artemisia cana*, which is accompanied by *Dasiophora fruticosa*, *Agrostis hiemalis*, *Dugaldia hoopesii*, and *Eriogonum subalpinum*. The mesophytic meadows on the tops of the plateaus which adjoin the dry alpine scrub instead of the spruce forest lack the *Artemisia cana* border, which would seem to indicate that this sagebrush association is an outpost from the forest formation, rather than a successor to the meadow.

Certain alpine species which are uncommon below 10,000 feet are found in the higher rocky meadows. *Oxyria digyna*, *Sibbaldia procumbens*, *Primula parryi*, *Synthlipsis laciniata*, *Polemonium confertum*, *Filix fragilis*, and *Allium cernuum* are all found in moist crevices on high shaded cliffs.

10. ALPINE SCRUB CLIMAX

On the summits of the High Plateaus, the subalpine forests often alternate with the dry alpine climax which occupies places where the soil is thin and exposure to the wind is great. The reduced size of the plants is evidence of the extreme exposure and the short season. This association seems to terminate a xerarch succession, but there is some evidence that a wet meadow may be replaced by it.

Placodium cinnabarinum and other crustose lichens (*Acarospora*, *Caloplaca*, *Lecanora rubina*, *L. saxicola*, and *Candelariella vitellina*) gain foothold on the smaller rock fragments as well as on the exposed

bedrock. Some foliose forms such as *Parmelia conspersa* and *Gyrophora hyperborea* also occur. The mosses *Tortula muralis* and *Hypnum revolutum* are seen in crevices with *Selaginella watsoni*. Apparently loose on stony soil is *Parmelia molliuscula*, a pale green foliose form which is blown about by the wind. Typical xerophytic alpine herbs follow. These are characterized usually by relatively large underground structures topped by a rosette of minute, often fleshy or hairy leaves and a short slender scape bearing the relatively large flowers. They develop rapidly when once the snow is gone, and mature their fruits before the short growing season is over. The commonest of these on the plateau summits are *Oreobroma pygmaea*, a fleshy leaved relative of our eastern spring beauty, *Androsace subumbellata*, *A. carinata*, *Sedum stenopetalum*, *Polygonum watsonii*, *Thlaspi glaucum* (?), *T. coloradense* (?), and a new *Thlaspi*, *Erigeron compositus* and its varieties *incertus* and *trifidus*, *Arenaria sajanensis*, *Draba mongollonica*, *D. crassifolia*, *Cerastium beerlingianum*, *Artemisia scopulorum*, *Achillea lanulosa alpicola*, *Senecio petrophilus*, and species of *Antennaria*. As the soil deepens the alpine grasses take possession. The dominant species is *Festuca ovina* and its variety *brachyphyllum*. *F. rubra*, *F. thurberi*, *Agropyron tenerum*, and a little black sedge are also common at this stage. Between the tufts of grasses *Pseudocymopterus montanus*, *Achillea*, and *Sibbaldia procumbens* are found. The short fescue, *Festuca ovina*, gives the tone to these summit landscapes, but counts made in a number of meter quadrats show that other species, such as *Oreobroma pygmaea*, *Androsace subumbellata*, *Achillea*, and *Pseudocymopterus montanus*, although minute and inconspicuous, are very numerous.

The shallow troughs which drain the ponds and lakes on the summits may begin with a wet meadow association. Along the water courses are sedges, but on the wet banks grows *Caltha rotundifolia* in fairly pure stands. *Polygonum bistortoides* (and sometimes its variety *linearifolia*) and *Pedicularis groenlandica* are next, then *Phleum alpinum*, *Deschampsia caespitosa*, *Stipa columbiana*, *Saxifraga rhomboidea*, a white and a new purple flowered *Thlaspi*, *Sieversia turbinata*, *Phacelia sericea*, *Polemonium confertum*, *Potentilla concinna*, *P. glaucophylla*, *Sibbaldia procumbens*, *Senecio petrophilus*, and *Pseudocymopterus montanus* come in on the mid-slopes; at the top of

the slopes are the grasses and their associates. Here the wet meadow seems to be a pioneer stage preceding the dry tundra.

Wherever lava blocks afford some protection from the wind, or on leeward slopes, taller, more mesophytic herbs come in. These include blue and yellow columbines, *Anemone globosa*, *Phacelia sericea*, *Carex festiva*, *Mertensia pratensis*, *Sieversia triflora*, *S. turbinata*, *S. ciliata*, *Potentilla diversifolia*, *Drymocallis fissa*, *Heuchera parvifolia*, *Polemonium confertum*, a white *Polemonium*, *Erigeron* spp., and taller grasses such as *Poa sandbergii*, *Blepharineuron tricholepis*, *Koeleria cristata*, and *Deschampsia caespitosa*.

These rocks and taller herbs sometimes afford enough protection to permit the alpine shrubs *Juniperus sibirica* and *Ribes lentum* to come in. These shrub mats are more common on the central part of Fish Lake Plateau where large lava blocks were scattered by the glacier than on the other plateaus where the rock fragments are mostly small. They probably introduce the subalpine forest islands which dot the landscape on the Aquarius Plateau, but on the smaller plateaus the forests so developed are seldom much more than mere clumps of stunted and gnarled timberline trees. Whether they can compete against the wind and eventually establish a real climax spruce forest is a question. The timberline here seems to be determined by wind and by depth of soil rather than by temperature. At present the summits of all these High Plateaus represent a line of tension between the subalpine forest climax and the alpine scrub climax. Whether the true climax here is the subalpine forest, which is often long delayed owing to the slow disintegration of the rock and to desiccation by the wind, or the xerophytic alpine scrub which occasionally may be preceded by a more mesophytic subclimax which will eventually give way to it, is yet unsettled. Possibly both associations are true climax formations here, but each in its own climatic zone; for the climate on a broad plateau like the Aquarius Plateau may differ considerably from that on an isolated peak at the same altitude. At any rate, on the broader plateaus such as Aquarius Plateau, the two associations run rather parallel while on small tables like Fish Lake Plateau and Thousand Lake Mt. and on peaks like Mt. Marvine, where the wind is stronger, the alpine scrub takes the lead.

Plant list

KEY TO SYMBOLS USED TO DENOTE ZONES:

- I, southern desert zone; IA, northern desert zone; IB, alkali desert
 II, southern semidesert zone; IIA, northern semidesert zone
 III, basal (western yellow pine) zone
 IV, montane forest zone
 V, subalpine forest zone
 VI, alpine meadow climax
 VII, alpine scrub climax

KEY TO SYMBOLS USED TO DENOTE HABITATS:

- X, xerophytic; XX, extremely xerophytic
 XM, xero-mesophytic
 M, mesophytic
 HM, hydro-mesophytic
 H, hydrophytic
 R, ruderal

I. LICHENS

(identified by the late Dr. PLITT of Baltimore, Md.)

- Acarospora bella* (Nyl.) Jatta..... crustose on lava
A. spp...... crustose on lava
Caloplaca spp...... crustose on lava
Candelariella vitellina Mull. Ary..... crustose on lava
Gyrophora hyperborea (Hoffm.) Mudd..... foliose on rocky soil
Lecanora rubina (Vill.) Wain..... semifoliose on rock
L. saxicola (Poll.) Ach..... semifoliose on rock
L. spp. (aspicilia?)..... semifoliose on rock
L. divaricata (L.) Ach..... fruticose on spruces
Parmelia conspersa Ach..... foliose on rock, soil
P. molliuscula Ach..... foliose on rock
Peltigera spp...... foliose on moist soil
Usnea spp...... fruticose on spruces

II. MOSSES

(identified by Dr. SEVILLE FLOWERS)

- Amblystegium riparium* var. *fluitans* L. & S..... VI HM
A. riparium var. *longifolium* (Schultz) B. & S..... VI HM
A. serpens B. & S..... V HM
Aulacomnium palustre Schwaegr..... IV, VI HM
Brachythecium idahense R. & C..... V M

<i>Bryum caespiticium</i> L.....	VI	HM
<i>B. capillare</i> L.....	VI	HM
<i>B. schleicheri</i> Schwaegr. (?).....	V	M
<i>B. spp.</i>	VI	HM
<i>Climacium americanum</i> Brid.....	VI	HM
<i>Cratoneuron filicinum</i> (L.) Roth.....	VI	HM
<i>Drepanocladus aduncus</i> var. <i>Kneiffii</i> form <i>intermedi-</i> us (B. & S.) Moenken.....	VI	HM
<i>D. uncinatus</i> (Hedw.) Warnst.....	VI	HM
<i>Hypnum revolutum</i> Nutt.....	VII	X
<i>Mnium affine</i> var. <i>rugicum</i> B. & S.....	VI	HM
<i>M. serratum</i> Schrad.....	V	M
<i>Philonotis fontana</i> (L.) Brid.....	IV, V, VI	HM
<i>Pohlia cruda</i> (L.) Lindb.....	VI	HM
<i>P. nutans</i> (Schreb.) Lindb.....	V	M
<i>Polytrichum juniperinum</i> Willd.....	V	M
<i>Swartzia montana</i> (Lank.) Lindb.....	V	HM
<i>Tortula muralis</i> (L.) Hedw.....	VII	XX

III. LIVERWORTS

<i>Conocephalum</i> spp.....	III, IV, V	HM
<i>Marchantia</i> spp.....	III, IV, V	HM

IV. VASCULAR PLANTS

A. Trees

<i>Abies concolor</i> Lindl.....	IV	M
<i>A. lasiocarpa</i> (Hook.) Nutt.....	V	M
<i>Acer interius</i> Britton.....	I, II	HM
<i>Alnus tenuifolia</i> Nutt.....	IV	HM
<i>Amelanchier alnifolia</i> Nutt.....	III, IV	XM
<i>A. oreophila</i> A. Nels.....	IIA	XM
<i>A. utahensis</i> Koehne.....	I	X
<i>Betula fontinalis</i> Sarg.....	II-IV	HM
<i>Celtis rugulosa</i> Rydb.....	I	HM
<i>Cercocarpus intricatus</i> Wats.....	II	X
<i>C. ledifolius</i> Nutt.....	IIA, III, IV	XM
<i>C. parvifolius</i> Nutt.....	IIA, III, IV	XM

<i>Fraxinus anomala</i> Torr.....	I HM
<i>Juniperus scopulorum</i> Sarg.....	II, III XM
<i>J. utahensis</i> (Engelm.) Lemm.....	II XM
<i>Picea engelmannii</i> (Parry) Engelm.....	V M
<i>P. pungens</i> Engelm.....	II, III, IV HM, XM
<i>Pinus aristata</i> Engelm.....	III XM
<i>P. edulis</i> Engelm.....	II XM
<i>P. flexilis</i> James.....	V XM
<i>P. ponderosa</i> Dougl.....	III XM
<i>Populus angustifolia</i> James.....	II HM
<i>P. aurea</i> Tidest.....	IV M
<i>P. fremontii</i> S. Watson.....	I HM
<i>P. trichocarpa</i> T. & G.....	II HM
<i>Prunus melanocarpa</i> (A. Nels.) Rydb.....	II, III, IV M
<i>Pseudotsuga mucronata</i> (Raf.) Sudw.....	IV, III, V M, XM
<i>Quercus utahensis</i> Rydb.....	IIA, III XM
<i>Salix lasiandra</i> Nutt.....	I HM

B. Shrubs

<i>Arctostaphylos platyphylla</i> (A. Gray) Kuntze.....	III XM
<i>A. uva-ursi</i> (L.) Spreng.....	III, IV, V XM
<i>Artemisia cana</i> Pursh.....	V, VI M
<i>A. filifolia</i> Torr.....	I X
<i>A. frigida</i> Willd.....	III, IV X
<i>A. tridentata</i> Nutt.....	IA to IV X
<i>A. tripartita</i> Rydb. (?).....	V, VI HM
<i>Atriplex canescens</i> (Pursh) Nutt.....	IB X
<i>A. confertifolia</i> (Torr. & Gray) S. Watson.....	IB X
<i>A. spp.</i>	IB X
<i>Ceanothus fendleri</i> Gray.....	III, IV X
<i>C. velutinus</i> Dougl.....	IV XM
<i>Chrysothamnus graveolens</i> (Nutt.) Greene....	IIA to IV X
<i>Clematis ligusticifolia</i> Nutt.....	I HM
<i>Coleosanthus microphylla</i> Gray.....	I X
<i>Cornus stolonifera</i> Michx.....	II, III HM
<i>Cowania stansburiana</i> Torr.....	I, II, III X
<i>Dasiophora fruticosa</i> (L.) Rydb.....	VI M

<i>Ephedra torreyana</i> S. Watson.....	I X
<i>E. viridis</i> Coville.....	I X
<i>Eriogonum corymbosum</i> Benth.....	I X
<i>E. effusum</i> Nutt.....	IIA XM
<i>E. microthecum</i> Nutt. (?).....	IIA XM
<i>E. (near polifolium</i> Benth.).....	IIA XM
<i>Fallugia paradoxa</i> (Don) Endl.....	I, II, III X
<i>Holodiscus dumosus</i> (Nutt.) Heller.....	IIA XM
<i>Juniperus sibirica</i> Burgsd.....	III, IV, V, VII XM
<i>Lepargyrea argentea</i> (Pursh) Greene.....	IV M
<i>L. canadensis</i> (L.) Greene.....	IV, V M
<i>L. rotundifolia</i> (Parry) Greene.....	I to III X
<i>Lonicera involucrata</i> Banks.....	IV M
<i>Odostemon fremontii</i> (Torr.) Rydb.....	I XM
<i>O. repens</i> (Lindl.) Cockerell.....	III, IV, V M
<i>Opulaster malvaceus</i> (Greene) Kuntze.....	IV, V M
<i>Pachystima myrsinites</i> (Pursh) Raf.....	III, IV, V M
<i>Philadelphus microphyllus</i> Gray.....	I X
<i>Phoradendron juniperinum</i> Engelm.... (parasite on juniper)	
<i>Purshia tridentata</i> DC.....	III, IV XM
<i>Rhus trilobata</i> Nutt. (?).....	I HM
<i>R. utahensis</i> L. N. Goodding.....	I X
<i>Ribes cereum</i> Dougl.....	IV, V XM
<i>R. inebrians</i> Lindl.....	III, IV XM
<i>R. lentum</i> (Jones) Coville & Rose.....	V, VII XM
<i>R. leptanthum</i> Gray.....	III XM
<i>R. niveum</i> Lindl.....	V M
<i>R. roezli</i> Regel.....	V M
<i>R. viscosissimum</i> Pursh (?).....	IV, V M
<i>Rosa fendleri</i> Crépín (?).....	III, IV XM
<i>R. manca</i> Greene (?).....	IV M
<i>R. puberulenta</i> Rydb.....	I HM
<i>R. pyrifera</i> Rydb. (?).....	IV M
<i>R. woodsii</i> Lindl.....	V HM
<i>Rubus hispidus</i> L.....	IV M
<i>R. strigosus</i> Michx.....	IV, V, VII XM
<i>Salix bebbiana</i> Sarg.....	V HM

<i>S. exigua</i> Nutt.....	IV HM
<i>S. lutea</i> Nutt. (?).....	IV HM
<i>S. pseudomyrsinites</i> var. <i>aequalis</i> Anderss. (?).....	V HM
<i>S. subcoerulea</i> Piper.....	IV HM
<i>Sambucus melanocarpa</i> Gray.....	III, IV XM
<i>S. microbotrys</i> Rydb.....	IV, V M
<i>Sarcobatus vermiculatus</i> (Hook.) Torr.....	IC X
<i>Sericotheca microphylla</i> Rydb.....	IIA XM
<i>Symphoricarpos longiflorus</i> Gray.....	IV X
<i>S. oreophilus</i> Gray.....	IV XM to M
<i>S. racemosus</i> Michx.....	III, IV XM
<i>Tetradymia canescens</i> DC. var. <i>inermis</i> Gray	
	IIA, III, IV X
<i>Toxicodendron rydbergii</i> Small.....	I XM
<i>Yucca harrimaniae</i> Trel.....	I, II X
<i>Y. spp.</i>	I, II X

C. Herbs

<i>Abronia elliptica</i> A. Nels.....	I, II X
<i>A. spp.</i>	III XM
<i>Achillea lanulosa</i> var. <i>alpicola</i> Rydb.....	V, VI M
<i>A. millefolium</i> L.....	III to V R
<i>Aconitum columbianum</i> Nutt.....	IV, V HM
<i>Agastache urticifolia</i> (Benth.) Rydb.....	V M
<i>Agoseris purpurea</i> (Gray) Greene.....	IV XM
<i>Agropyron spicatum</i> (Pursh) Scribn. & Wheeler.....	III XM
<i>A. tenerum</i> Vasey.....	IV HM
<i>Agrostis hiemalis</i> (Wolf) B.S.P.....	III, IV HM
<i>Allionia spp.</i>	I X
<i>Allium brandegii</i> Hook.....	III, IV HM
<i>A. brevistylum</i> Wats.....	V HM
<i>A. cernuum</i> Roth.....	VII HM
<i>Allocarya scopulorum</i> Greene.....	IV M
<i>Alopecurus aequalis</i> Sobol.....	IV HM
<i>A. geniculatus</i> L.....	IV HM
<i>Ambrosia psilostachya</i> DC.....	I X
<i>Andropogon scoparius</i> Michx.....	I X

<i>Androsace carinata</i> Torr. (?)	VII X
<i>A. diffusa</i> Small	IV, V M
<i>A. subumbellata</i> (A. Nels.) Small	VII X
<i>Anemone globosa</i> Nutt.	VI HM
<i>Antennaria aprica</i> Greene	III X
<i>A. dimorpha</i> (Nutt.) Torr. & Gray	VI M
<i>A. microphylla</i> Rydb.	IV HM
<i>A. parvifolium</i> Nutt.	VI HM
<i>Apocynum androsaemifolium</i> L.	IV M
<i>Aplopappus</i> spp.	I X
<i>Aquilegia coerulea</i> James	IV, V, VI M
<i>A. coerulea albiflora</i> Gray	IV, V, VI M
<i>A. flavescens</i> S. Wats.	VII XM
<i>A. pinetorum</i> Tidest. (?)	IV M
<i>Arabis drummondii</i> Gray	IV M
<i>Arenaria aculeata</i> Wats.	I X
<i>A. sajanensis</i> Willd.	VII X
<i>Argemone hispida</i> Gray	I R
<i>Aristida fendleriana</i> Steud.	IV X
<i>Arnica cordifolia</i> Hook.	V M
<i>A. ocreata</i> A. Nels.	V HM
<i>Artemisia scopulorum</i> Gray	VII X
<i>A. wrightii</i> Gray	II X
<i>Asclepias cryptoceras</i> Wats.	I XM
<i>A. incarnata</i> L.	I XM
<i>A. labriiformis</i> M. E. Jones	I X
<i>Aster adscandens</i> Lindl. (?)	IV HM
<i>A. glaucodes</i> Blake	IV HM
<i>Astragalus diversifolius</i> Gray	II XM
<i>A. thompsonae</i> S. Wats.	I, II X
<i>Atriplex</i> spp.	IB X
<i>Batrachium grayanum</i> (Freyn.) Rydb.	IV H
<i>B. trichophyllum</i> (Chaix.) Barsch.	IV, V H
<i>Blepharineuron tricholepis</i> (Torr.) Nash	VII X
<i>Bouteloua gracilis</i> (H.B.K.) Lag.	I to III X
<i>B. hirsuta</i> Lag.	IV X
<i>Bromus ciliatus</i> L.	IV HM

<i>B. inermis</i> Leyss.....	III R
<i>Calochortus nuttallii</i> T. & G.....	II, III XM
<i>Caltha rotundifolia</i> Greene.....	VI HM
<i>Campanula parryi</i> Gray.....	IV HM
<i>C. uniflora</i> L. (?).....	VII X
<i>Cardamine cordifolia</i> Gray.....	V HM
<i>C. infausta</i> Greene.....	III to VI HM
<i>Carex ebenea</i> Rydb.....	VI HM
<i>C. engelmannii</i> Bailey.....	VI HM
<i>C. festiva</i> Dewey.....	VII X
<i>C. lanuginosa</i> Michx.....	IV HM
<i>C. multinoda</i> Bailey.....	IV HM
<i>C. siccata</i> Dewey.....	V, VI HM
<i>C. variabilis</i> Bailey.....	VI HM
<i>C. spp.</i>	VI HM
<i>Castilleja arcuata</i> Rydb.....	V M
<i>C. exilis</i> A. Nels.....	IV HM
<i>C. flava</i> A. Nels.....	IV X
<i>C. lauta</i> A. Nels.....	V M
<i>C. linariaefolia</i> Benth.....	V M
<i>C. linoides</i> Gray (?).....	IIA X
<i>C. miniata</i> Dougl. (?).....	V M
<i>C. parvula</i> Rydb. (?).....	IV X
<i>C. rhexifolia</i> Rydb. (?).....	IV, V HM
<i>Catabrosa aquatica</i> (L.) Beauv.....	IV, V H
<i>Cenchrus pauciflorus</i> Benth.....	I HM
<i>Cerastium beeringianum</i> C. & S.....	VII X
<i>Chaenactis alpina</i> (Gray) Jones (?).....	VII X
<i>C. douglasii</i> H. & A.....	IIA, III, IV X
<i>Chamaesyce fendleri</i> (T. & G.) Small.....	I, II X
<i>Chamaenerion angustifolium</i> (L.) Scop.....	IV HM
<i>Chrysopsis</i> spp.....	I HM
<i>Chrysothamnus</i> spp.....	III, IV X
<i>Chylismia</i> spp.....	I X
<i>Clematis pseudoalpina</i> (Kuntze) A. Nels.....	III XM
<i>Clementsia rhodantha</i> (Gray) Rose.....	VI HM
<i>Collomia linearis</i> Nutt.....	IV M

<i>Comandra pallida</i> A. DC.....	IIA, III, IV XM
<i>Corallorrhiza maculata</i> Raf. parasite on roots.....	III XM
<i>Crepis acuminata</i> Nutt.....	IV M
<i>Datura meteloides</i> DC.....	I XM
<i>Delphinium cockerellii</i> A. Nels.....	V M
<i>D. subalpinum</i> (Gray) A. Nels.....	IV, V HM
<i>Deschampsia caespitosa</i> (L.) Beauv.....	VI HM
<i>Dodecatheon pauciflorum</i> (Durand) Greene.....	VI HM
<i>Draba aurea</i> Vahl.....	V X
<i>D. crassifolia</i> Graham (?).....	VII M
<i>D. mongollonica</i> Greene.....	VII X
<i>D. spectabilis</i> Greene (?).....	VII X
<i>Drymocallis fissa</i> (Nutt.) Rydb.....	VI M
<i>D. spp.</i>	VI M
<i>Dugaldia hoopesii</i> (Gray) Rydb.....	VI M
<i>Echinocactus xeranthemoides</i> Coulter.....	I X
<i>E. spp.</i>	I X
<i>Echinocereus fendleri</i> (Engelm.) Ruml. (?).....	I X
<i>E. goniocanthus</i> (Engelm.) Lem. (?).....	I X
<i>E. mojavenis</i> (Engelm.) Ruml.....	I X
<i>E. triglochidiatus</i> (in Britton & Rose).....	I X
<i>Eleocharis acicularis</i> (L.) Roem. & Schultz.....	IV, V H
<i>E. palustris</i> (L.) Roem. & Schultz.....	IV, V H
<i>Epilobium adenocaulon</i> Hausskn.....	IV, V HM
<i>E. hornemannii</i> Reichert (?).....	V, VII HM
<i>E. ovatifolium</i> Rydb.....	IV H
<i>Equisetum arvense</i> L.....	III, IV, V HM
<i>E. hiemale</i> L.....	III, IV H
<i>Erigeron argentatus</i> Gray.....	I, II X
<i>E. bloomeri</i> Gray.....	IV X
<i>E. compositus</i> Pursh.....	V, VII X
<i>E. compositus discoideus</i> Gray or incertus A. Nels... ..	VII X
<i>E. compositus trifidus</i> Gray.....	VII X
<i>E. eatonii</i> Gray (?).....	IV M
<i>E. flagellaris</i> Gray.....	IV X
<i>E. formosissimum</i> Greene.....	VI M
<i>E. leiomerus</i> Gray.....	I, II X

<i>E. macranthus</i> Nutt.....	VI	M
<i>E. salsuginosus</i> Gray.....	IV	HM
<i>E. superbus</i> Greene.....	VI	HM
<i>E. ursinus</i> D. C. Eaton (?).....	IV, V	M
<i>E. vetensis</i> Rydb.....	III	XM
<i>Eriogonum alatum</i> Torr.....	III	XM
<i>E. inflatum</i> Torr.....	I	X
<i>E. jamesii</i> Benth.....	IV	X
<i>E. ovalifolium</i> Nutt.....	I, II	X
<i>E. piperi</i> Greene.....	VI	M
<i>E. racemosum</i> Nutt.....	IIA, III, IV	X
<i>E. stellatum</i> Benth.....	III, IV	X
<i>E. subalpinum</i> Greene.....	VI	M
<i>E. umbellatum</i> Torr.....	III, IV	XM
<i>E. spp.</i>	other species in all zones	
<i>Euphorbia lurida</i> Engelm. or		
<i>Tithymalus luridus</i> (Engelm.) Woot. & Standl.....	III	XM
<i>Eurotia lanata</i> (Pursh) Moq.....	IB	X
<i>Festuca ovina</i> L.....	V, VII	X, XM
<i>F. ovina brachyphylla</i> Schult.....	V, VII	X
<i>F. idahoensis</i> Elmer.....	IV	X
<i>F. thurberi</i> Vasey.....	V, VII	XM
<i>Filix fragilis</i> (L.) Underw.....	IV to VII	XM
<i>Fragaria bracteata</i> Heller.....	V	HM
<i>F. glauca</i> (S. Wats.) Rydb.....	V	HM
<i>Franseria acanthicarpa</i> (Hook.) Coville.....	I	X
<i>Frasera speciosa</i> Griseb.....	IV, V	HM
<i>Galium boreale</i> L.....	IV	HM
<i>Gayophytum ramosissimum</i> T. & G.....	IV	X
<i>Gentiana affinis</i> Griseb.....	V	HM
<i>G. calycosa</i> Griseb. (?).....	VI	HM
<i>G. elegans</i> A. Nels.....	IV	HM
<i>G. heterosepala</i> Engelm.....	VI	HM
<i>G. plebeja</i> Cham.....	VI	HM
<i>Geranium carolinianum</i> L.....	IV	XM
<i>G. richardsonii</i> F. & M.....	IV, V	M
<i>G. viscosissimum</i> Fisch. & Mey.....	IV to VII	M

<i>Geum macrophyllum</i> Willd.....	IV	HM
<i>G. strictum</i> Ait.....	IV	HM
<i>Gilia aggregata</i> (Pursh) Spreng.....	III, IV	X
<i>G. dixonae</i> A. Nels. 1934.....	I	X
<i>G. pulchella</i> Dougl.....	IV	X
<i>Glyceria striata</i> Hitch.....	IV	HM
<i>Gnaphalium uliginosum</i> L.....	VI	HM
<i>Gutierrezia filifolia</i> Greene.....	III	X
<i>G. spp.</i>	III, IV	X
<i>Habenaria elegans</i> (Lindl.) Boland.....	IV	HM
<i>H. unalaskensis</i> (Spreng.) Wats.....	IV	HM
<i>Halerpestes cymbalaria</i> (Pursh) Greene.....	I to V	HM
<i>Heuchera parvifolia</i> Nutt.....	V	M
<i>Hilaria jamesii</i> (Torr.) Benth.....	I, II	X
<i>Hippuris vulgaris</i> L.....	IV, V	H
<i>Hordeum nodosum</i> L.....	IV	HM
<i>Hymenoxys helenioides</i> Rydb.....	V, VI	HM
<i>H. odorata</i> (DC.) Britt.....	III	X
<i>H. richardsonii</i> (Hook.) Ckll.....	V	R
<i>Hypericum formosum</i> H.B.K.....	IV	HM
<i>H. scouleri</i> Hook.....	IV	HM
<i>Iris missouriensis</i> Nutt.....	IV	HM
<i>Iva axillaris</i> Pursh.....	I	X
<i>Jonesiella asclepiadoides</i> Rydb.....	I	X
<i>Juncus balticus</i> Willd.....	III to VI	H
<i>J. filiformis</i> L.....	IV, V	HM
<i>J. saximontanus</i> A. Nels.....	IV, V	HM
<i>Kelloggia galioides</i> Torr.....	IV	M
<i>Koeleria cristata</i> L.....	VI	HM
<i>Lappula floribunda</i> (Lehm.) Greene.....	IV	XM
<i>L. occidentalis</i> (S. Wats.) Greene.....	IV	XM
<i>Lathyrus leucanthus</i> Rydb.....	IV, V	M
<i>L. spp.</i>	V	M
<i>Lavauxia flava</i> A. Nels.....	IV, V	M
<i>L. howardii</i> M. E. Jones.....	V	HM
<i>Leontodon scopulorum</i> Rydb.....	V	HM
<i>Lepidium jonesii</i> Rydb.....	I	XM

<i>Lesquerella alpina</i> (Nutt.) Wats.....	III X
<i>Ligusticum porteri</i> Coulter & Rose.....	IV M
<i>Linum lewisii</i> Pursh.....	IV M
<i>Lithospermum multiflorum</i> Torr. Wats.....	IV M
<i>Lotus wrightii</i> (Gray) Greene.....	III, IV XM
<i>Lupinus alpestris</i> A. Nels.....	III, IV, V XM
<i>L. argenteus</i> Nutt.....	IIA X
<i>L. lepidus</i> Dougl.....	III XM
<i>L. parviflorus</i> Nutt.....	V HM
<i>L. pseudoparviflorus</i> Rydb. (?).....	V HM
<i>L. spp.</i>	II to VII
<i>Lygodesmia exigua</i> Gray.....	IIA X
<i>L. juncea</i> (Pursh) D. Don.....	II X
<i>L. spinosa</i> Nutt. or <i>Pleiacanthus spinosus</i> (Nutt.) Rydb.	II to IV X
<i>Melilotus alba</i> Desv.....	I R, HM
<i>M. officinalis</i> (L.) Lam.....	I R, HM
<i>Mertensia arizonica</i> Greene (?).....	IV HM
<i>M. pratensis</i> Heller.....	IV, V HM
<i>Microseris spp.</i>	IV X
<i>Mimulus guttatus</i> DC.....	IV, V H
<i>Mitella spp.</i>	V M
<i>Monardella odoratissima</i> Greene.....	V XM
<i>Moneses uniflora</i> (L.) Gray.....	V HM
<i>Montia chamissoi</i> (Ledeb.) Tidest.....	V HM
<i>Muhlenbergia asperifolia</i> Nees. & Mey.....	IB HM
<i>Myosurus aristatus</i> Benth.....	IV, V HM
<i>Myriophyllum spicatum</i> L.....	IV H
<i>Opuntia fragilis</i> (Nutt.) Haw.....	II, III, IV X
<i>O. polyacantha</i> Haw. (?).....	I, II X
<i>O. rhodantha</i> Schum.....	II X
<i>O. rutila</i> Nutt.....	I, II X
<i>O. xanthostemma</i> Schum.....	II X
<i>O. spp.</i>	I, II X
<i>Oreobroma pygmaeum</i> (Gray) Howell.....	VII X
<i>Oreocarya flava</i> A. Nels. (?).....	I X
<i>O. setosissima</i> (Gray) Greene (?).....	IV XM

<i>O.</i> (near <i>suffruticosa</i> (Torr.) Greene).....	III X
<i>Oreoxis alpina</i> (Gray) C. & R.....	V M
<i>Orobanche ludoviciana</i> Nutt. parasitic on <i>Chrysotham-</i> <i>nus</i>	II X
<i>Orthocarpus luteus</i> Nutt.....	V M
<i>Oryzopsis hymenoides</i> (Roem. & Schult.) Ricker.....	II X
<i>Osmorrhiza obtusa</i> (Coulter & Rose) Fernald.....	IV, V M
<i>Oxyria digyna</i> (L.) Hill.....	VII XM
<i>Oxytropis deflexa</i> (Pall.) DC. (?).....	V XM
<i>Pachylophus macroglottis</i> Rydb.....	IV X
<i>Parnassia parvifolia</i> DC.....	V HM
<i>Pedicularis bracteosa</i> Benth.....	VI XM
<i>P. groenlandica</i> Retz.....	VI HM
<i>P. groenlandica surrecta</i> (Benth.) Greene.....	VI HM
<i>P. parryi</i> Gray.....	VI M
<i>Pediocactus simpsonii</i> (Engelm.) Britton & Rose.....	III, IV X
<i>Pentstemon arenicola</i> A. Nels.....	III X
<i>P. caespitosus</i> Nutt.....	II XM
<i>P. eatonii undosus</i> M.E. Jones.....	II X
<i>P. ophianthus</i> Pennell.....	II XM
<i>P. pachyphyllus</i> Gray.....	III XM
<i>P. procerus</i> Dougl.....	VI M
<i>P. procerus pulverens</i> Pennell.....	VI M
<i>P. strictus</i> Benth.....	IV X
<i>P. subglaber</i> Rydb.....	V M
<i>P. torreyi</i> Gray (?).....	III XM
<i>P. whippleanus</i> Gray.....	V HM
<i>P. spp.</i>	I to VII X to M
<i>Phacelia corrugata</i> A. Nels.....	I XM
<i>P. idahoensis</i> Henders.....	IV M
<i>P. sericea</i> Gray.....	IV, V, VI, VII M, XM
<i>P. spp.</i>	IIA X
<i>Phleum alpinum</i> L.....	VI HM
<i>Phlox austromontana</i> Coville.....	III XM
<i>P. canescens</i> Torr. & Gray.....	I XM
<i>P. cortezana</i> A. Nels.....	V M
<i>P. stansburyi</i> (Torr.) Heller.....	III, IV XM

<i>Physaria didymocarpa</i> Gray.....	III XM
<i>Poa ampla</i> Merr.....	VI M
<i>P. fendleriana</i> (Steud.) Vasey.....	IV, V M
<i>P. longiligula</i> Scribn. & Wms.....	V M
<i>P. pratensis</i> L.....	IV, V M
<i>P. sandbergii</i> Vasey.....	VI, VII M
<i>Polemonium albiflorum</i> Eastw. (?).....	VII X
<i>P. confertum</i> Gray.....	VII X
<i>P. foliosissimum</i> Gray (?).....	IV HM
<i>P. pulcherrimum</i> Hook.....	VII X
<i>P. viscosum</i> Nutt. (?).....	VII X
<i>Polygonum amphibium</i> L.....	IV, V H
<i>P. bistortoides</i> Pursh.....	VI, VII HM
<i>P. bistortoides linearifolia</i> S. Wats.....	VI, VII HM
<i>P. watsonii</i> Small.....	VII X
<i>Potamogeton americanus</i> Schlecht. & Cham.....	IV, V H
<i>P. spp.</i>	IV, V H
<i>Potentilla concinna</i> Rich.....	VII X
<i>P. (near concinnaeformis</i> Rydb.).....	VII X
<i>P. dichroa</i> Rydb.....	III XM
<i>P. diversifolia</i> Lehm.....	IV XM
<i>P. effusa</i> Dougl., Lehm.....	V HM
<i>P. fastigiata</i> Nutt.....	IV HM
<i>P. glaucophylla</i> Lehm.....	IV, HM to VII XM
<i>P. gracilis</i> Dougl.....	IV M
<i>P. hippiana</i> Lehm. (?).....	IV HM
<i>P. intermittens</i> Rydb. (?).....	IV HM
<i>P. monspeliensis</i> L.....	V HM
<i>P. nuttallii</i> Lehm.....	IV HM
<i>P. pennsylvanica</i> L.....	III HM
<i>P. propinqua</i> Rydb.....	IV HM
<i>P. spp.</i>	IV-VII
<i>Primula parryi</i> Gray.....	V, VII HM
<i>Pseudocymopterus montanus</i> (Gray) Coulter & Rose	
	III, IV, V XM
<i>P. spp.</i>	VII X
<i>Pyrola asarifolia</i> Michx.....	V HM

<i>P. chlorantha</i> Sw.....	V	HM
<i>P. secunda</i> L.....	III, IV	HM
<i>Quamoclidion froebelii</i> (Behr.) Standl.....	I	XM
<i>Ranunculus alpeophilus</i> A. Nels.....	V	HM
<i>R. calthaeiflorus</i> Greene.....	VI	HM
<i>R. cardiophyllus</i> Hook.....	VI	HM
<i>R. cymbalaria</i> Pursh or <i>Halerpestes cymbalaria</i> (Pursh) Greene.....	I to V	HM
<i>R. escholtzii</i> Schlect.....	IV	HM
<i>R. inamoenus</i> Greene.....	V	HM
<i>R. montanensis</i> Rydb.....	IV	HM
<i>R. sceleratus</i> L.....	III	HM
<i>Roripa curvipes</i> Greene.....	V	HM
<i>R. sinuata</i> (Nutt.) A.S.H.....	IV	HM
<i>Rumex mexicanus</i> Meisn.....	IV	HM
<i>Sagina saginoides</i> (L.) Britton.....	VII	HM
<i>Salsola pestifer</i> A. Nels.....	I	X
<i>Saxifraga arguta</i> D. Don.....	V	M
<i>S. integrifolia sierrae</i> Coville.....	V	M
<i>S. rhomboidea</i> Greene.....	V	HM
<i>Sedum stenopetalum</i> Pursh.....	VII	X
<i>S. spp.</i>	VII	X
<i>Selaginella mutica</i> D. C. Eaton.....	II	X
<i>S. watsoni</i> Underw.....	VII	X
<i>Senecio atratus</i> Greene.....	V	M
<i>S. crocatus</i> Rydb.....	IV	HM
<i>S. cymbalarioides</i> Nutt.....	VI	M
<i>S. multilobatus</i> Torr. & Gray.....	IV	X
<i>S. mutabilis</i> Greene.....	IV	HM
<i>S. petrophilus</i> Greene.....	VII	X
<i>S. purshiana</i> Nutt. (?).....	VII	X
<i>S. triangularis</i> Hook.....	V	X
<i>S. spp.</i> several other species in zones	III-VII	
<i>Sibbaldia procumbens</i> L.....	VII	XM
<i>Sidalcea candida</i> Gray.....	IV	HM
<i>Sieversia ciliata</i> G. Don.....	VI, VII	M
<i>S. triflora</i> (Pursh) R. Br.....	VI, VII	XM

<i>S. turbinata</i> (Rydb.) Greene.....	VII X
<i>Silene antirrhinus</i> L.....	V M
<i>Sisyrinchium angustifolium</i> Nutt.....	IV HM
<i>Sitanion hystrix</i> (Nutt.) J. C. Smith.....	III X
<i>Sium cicutaefolium</i> Gmelin.....	V HM
<i>Smilacina stellata</i> (L.) Desf.....	III HM
<i>Solidago bigelovii</i> Gray.....	IIA X
<i>Sophia filipes</i> (Gray) Heller.....	VII X
<i>S. hartwegiana</i> (Fourn.) Greene.....	IV HM
<i>Sphaeralcea grossulariaefolia</i> (H. & A.) Rydb.....	I, II X
<i>Stanleya integrifolia</i> James.....	I HM
<i>Stipa columbiana</i> Macoun.....	IV to VII X
<i>S. comata intermedia</i> Scribn.....	IV X
<i>S. speciosa</i> Trin. & Rupr.....	I, II X
<i>Synthyris laciniata</i> (Gray) Rydb.....	V HM
<i>Taraxacum officinale</i> Web.....	II to VII R
<i>Taraxia breviflora</i> (T. & G.) Nutt.....	IV, V HM
<i>T. subacaulis</i> (Pursh) Rydb. (?).....	V M
<i>Thalesia fasciculata</i> (Nutt.) Britton, parasite on <i>Artemisia</i>	IIA X
<i>Thalictrum fendleri</i> Engelm.....	IV HM
<i>T. megacarpum</i> Torr.....	V M
<i>T. occidentale</i> Gray.....	V M
<i>Thermopsis montana</i> Nutt.....	IV, V, VI M
<i>Thlaspi coloradense</i> Rydb. (?).....	VII X
<i>T. glaucum</i> A. Nels. (?).....	VII X
<i>T. spp.</i> —a new purple-flowered species.....	VII X
<i>Tithymalus luridus</i> (Engelm.) Woot. & Small.....	III XM
<i>Townsendia arizonica</i> Gray.....	I X
<i>T. spp.</i>	I X
<i>Trifolium rydbergii</i> Greene.....	VI M
<i>T. repens</i> Wheeler.....	IV HM, R
<i>Trisetum subspicatum</i> (L.) Beauv.....	IV M
<i>Urtica breweri</i> S. Wats.....	IV HM
<i>Valeriana ceratophylla</i> (Hook.) Piper.....	IV HM
<i>Veratrum speciosa</i> Rydb.....	V HM
<i>Veronica alpina</i> L.....	IV HM

<i>V. americana</i> Schwein.....	III	HM
<i>V. serpyllifolia</i> L.....	IV	HM
<i>V. wormskjoldii</i> Roem. & Schult.....	V	HM
<i>Vicia americana</i> Michx.....	IV	M
<i>Viola macloskeyi</i> Lloyd or <i>V. orbiculata</i> Geyer.....	V	HM
<i>V. nephrophylla</i> Greene.....	III	HM
<i>Woodsia oregana</i> D. C. Eaton.....	III	XM
<i>Wyethia scabra</i> Hook.....	I	X
<i>Zygadenus elegans</i> Pursh.....	V, VI	HM

Summary

1. An ecological survey was made of the vegetation of the region between the 111th and the 112th meridians west of Greenwich and the 38th and 39th parallels north of the equator. It lies northeast of Bryce Canyon and northwest of the Henry Mts.

2. The vegetation in this region has been little disturbed except to a small extent by lumbering and to a somewhat greater extent by grazing.

3. Studies were made from the rock desert regions in the eastern part of this quadrat up to the summits of the plateaus included within its borders, namely, Aquarius, Thousand Lake, Fish Lake, and Awapa of the High Plateaus and the monoclines known as the Water Pocket Flexure and Miner's Mountain.

4. The High Plateaus are glaciated, lava-capped uplifts due to faulting, whose summits are 11,000 feet and more in altitude. The Water Pocket Flexure and Miner's Mountain are monoclines of sedimentary strata which reach to 8250 feet in altitude and are dissected by numerous gorges.

5. The climate varies from desert in the lowlands at 5000 feet where the annual precipitation is 5 to 6 inches to alpine on the summits.

6. There is a wide variety of soils, both residual and transported.

7. The flora includes representative formations from southern desert to alpine scrub, the lowlands lying on the outskirts of Lower Sonoran territory and the summits on the tension line between the subalpine forest and the arctic-alpine desert.

8. The southern flora extends up the tributaries of the Colorado

system, but corresponding levels on the Great Basin slopes of the tables lack these species.

9. The timber line is determined by wind rather than by temperature, so the broader the summit the better the development of forest. Small tables and isolated peaks are occupied mostly by alpine scrub; larger tables, by parklike arrangements of scrub and forest.

10. As far as possible the various successions to the climax in each climatic zone were worked out.

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